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CALL FOR ECONOMIC SUSTAINABILITY -

EUROPEAN RENEWABLE ENERGY SUPPORT SCHEMES AND THE MARKET

Thesis submitted in partial fulfilment of the requirements for the degree of Master in Science (Technology)

Helsinki, 24.09.2014

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Abstract of master's thesis

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Abstract:

This thesis provides the historical and contextual background, drivers, and assessment of harmonising current heterogeneous national renewable energy support schemes into a common European alternative that would outweigh the status quo, most noticeably in cost-efficiency and market orientation.
National support schemes have developed in accordance with a currently outdated concept of renewables where their share in overall production and technological maturity has been low. As renewable sources of energy nearing grid parity are increasingly deployed to electricity markets, new issues, including market distortion and cost elevation, have emerged. These new aspects and the resulting new requirements will have to be taken into account when comparing different alternatives for future renewable energy support.
Available research on the subject is partially out of date. The topic should now be reintroduced, since during the previous more intense period of debate over the harmonisation of support schemes across Europe, renewable technologies were still far from their current level of development.
This thesis attempts to merge available research with currently available data and prevailing political and economic atmospheres in order to produce a viable framework for future renewable energy support.
The thesis starts with relevant knowledgebase build-up in chapters 1 to 7, including electricity markets, tracking and support. Chapter 8 presents most of the relevant figures used in chapters 9 and 10 in estimating future requirements for renewable energy support and the adaptability of current support schemes to fulfil these objectives. Chapters 11 to 13 present and discuss the conclusions of this thesis.
This research suggests that a more international approach should be taken in supporting more mature renewable technologies. In more detail, it would require a multilateral market-based quota system – best achieved by introducing a European Tradable Green Certificate scheme based on current institution and market of Guarantee of Origin.

Keywords: renewable energy, support scheme, energy policy, tradable green certificates, guarantee of origin, feed-in tariff, feed-in premium

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Tiivistelmä:

Tämä diplomityö arvioi historialliseen kehitykseen ja viimeaikaisiin muutoksiin nojaten mahdollisuutta ja tarvetta viedä nykyiset kansalliset uusiutuvan energian tukimuodot lähemmäksi toivottua Euroopan laajuista ratkaisua, joka olisi sekä markkinalähtöisempi että kustannustehokkaampi tapa edistää uusiutuvan energian tuotantoa.

Pohja, jolle nykyiset tukimuodot perustuvat, on osittain vanhentunut. Uusiutuvat energianlähteet eivät enää vastaa marginaalisesta sähkömarkkinaosuudesta ja kypsemmät uusiutuvan energian teknologiat lähenevät markkinoilla pariteettia perinteisiin tuotantomuotoihin verrattuna. Lisääntynyt uusiutuva tuotanto ja uusiutuvien markkinaosuus ovat luoneet uusia vaatimuksia ja ongelmia, jotka enenevässä määrin vaarantavat sähkömarkkinoiden sekä taloudellista että teknistä vakautta. Nämä aspektit on huomioitava suunniteltaessa tulevaisuuden tukimekanismeja.

Saatavilla oleva tutkimustieto vaatii osittain päivitystä, sillä se rakentuu olettamuksille uusiutuvan energian vain vähäisestä tuotannosta ja uusiutuvien teknologien varhaisesta kehityksen asteesta. Johtuen radikaalista kehityksestä sekä tuotantomäärissä että kilpailukyvyssä, ajatus tukimuotojen sulautumisesta Euroopassa pitäisi nostaa uudelleen esille.

Tämä työ pyrkii yhdistämään saatavilla olevan tutkimusmateriaalin ajan tasalla olevaan tietoon sekä vallitsevaan poliittiseen ja taloudelliseen ilmapiiriin tuottaakseen uskottavan rakenteen uusiutuvan energian tukemiseksi tulevaisuudessa.

Tulokset osoittavat, että kypsempiä uusiutuvia teknologioita pitäisi tukea kansainvälisemmin markkinalähtöisillä tukimekanismeilla. Tämä tarkoittaisi käytännössä, kuten tämä tutkimus osoittaa, Euroopan laajuista sertifikaattimarkkinoihin perustuvaa kiintiömuotoista tukea, joka olisi parhaiten saavutettavissa hyödyntämällä nykyistä alkuperätakuu-instituutiota ja sen olemassa olevia markkinoita.

Avainsanat: uusiutuva energia, tukimekanismi, energiapolitiikka, vihreä sertifikaatti, alkuperätakuu, syöttötariffi, preemio

Foreword

I owe the most in completing this thesis to my instructor Lic. Sc. (Tech) Marko Lehtovaara, who has been a source of steady support from the initial pin-pointing of this topic to the final reviews of the complete thesis. I am equally grateful for the precious input and comments from my supervisor Professor Sanna Syri, who has guided the initial idea of the thesis toward a more academic publication.

I would also like to thank Grexel Systems Ltd. for providing the position, funding and means for completing this study. I am very grateful to all of my colleagues for the motivation and support they provided during these months, and for filling the gaps of knowledge with their unbelievable expertise.

Martin Aalto - Helsinki, 24.09.2014

Note to the reader: Reference system of the thesis

When a reference is provided inside a sentence, it is the source of information strictly for that sentence.

Example: This is sentence A (Author A., 2000).

When a reference forms its own sentence, it is the source of information for everything after the previous reference.

Example: This is sentence A (Author A., 2000). This is sentence B1. This is sentence B2. (Author B., 2000)

In such case Author B. would be the source of information for both sentences B1 and B2, and Author A. for sentence A. One reference can at most be the source of information for one paragraph, if it is provided at the end of a paragraph, which contains no other references.

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List of Abbreviations

ACER	The Agency for the Cooperation of Energy Regulators
AIB	The Association of Issuing Bodies
CACM	Capacity Allocation and Congestion Management
CB	Competent Body
CBT	Contract Based Tracking
CCS	Carbon Capture and Storage
CSP	Concentrated Solar Power
DSM	Demand Side Management
DSO	Distribution System Operator
EAM	European Attribute Mix
EC	European Commission
EECS	European Energy Certification System
ENTSO-E	The European Network for Transmission System Operators (Electricity)
ERGEG	European Regulators Group for Electricity and Gas
ERI	Electricity Regional Initiative
ETS	Emissions Trading Scheme
EU	The European Union
EUROPEX	The Association of European Energy Exchanges
EWEA	European Wind Energy Association
FIP	Feed-in Premium
FIT	Feed-in Tariff
GHG	Greenhouse Gas
GO	Guarantee of Origin

IB	Issuing Body
IEA	The International Energy Agency
IEM	Internal Energy Market
IIEA	The Institute of International ans European Affairs
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LCOE	Levelised Cost of Energy
LTMC	Long-Term Marginal Cost
MC	Marginal Cost
MDC	Marginal Damage Cost
MEC	Marginal External Cost
MNPB	Marginal Net Private Benefit
MP	Marginal Profit
MS	Member State
NRA	National Regulatory Authority
NREAP	National Renewable Energy Action Plan
OECD	The Organisation for Economic Co-operation and Development
OPL	Optimal Pollution Level
PURPA	Public Utility Regulatory Policy Act
PV	Photovoltaics
RA	Regulative Authority
RE-DISS	Reliable Disclosure Systems for Europe
REN21	Renewable Energy Policy Network for the 21st Century

RES	Renewable Energy Sources
RES-E	Renewable Energy Sources of Electricity
RO	Registry Operator
STMC	Short-Term Marginal Cost
TAC	Tradable Accounting Certificates
TGC	Tradable Green Certificate
TSO	Transmission System Operator
VPP	Virtual Power Plant

1. Introduction

"Climate action is central for the future of our planet, while a truly European energy policy is key for our competitiveness."

- European Commission President Jose Manuel Barroso (22nd Jan 2014)

The field of energy is changing. Europe, along with the rest of the world, is struggling towards a low-carbon society where key priorities of competitiveness, security of supply and sustainability are balanced and provide a stable environment for decades to come. The transition is driven by a paradigm shift in overlapping fields of sociology and economy as well as political, social and natural sciences. In this shift, it is becoming increasingly common for different objectives to be paralleled with drivers of ecological and sustainable development.

Europe will soon reach its 2020 targets. In the field of renewable energy, this has mainly been due to national support mechanisms helping emerging clean technologies compete with conventional production units. However, the support schemes, lacking a common framework, have formed a very heterogeneous set of energy policies that are tightly constrained by national borders. As renewables are increasingly deployed to the soon-united electricity markets, previously unforeseen consequences begin to emerge and interfere with other market dynamics. Future energy frameworks will have to address these issues, along with other highlighted objectives stemming from current growth in policy costs and lack of harmonisation.

Published research is rich with different assessments of national support policies and their effectiveness in lifting renewables from their initial stages to current levels of deployment. Major trends in this branch of science are covered in this thesis. Building on the gathered body of knowledge, this thesis attempts to merge past research results with up-to-date data and the changes in political and financial atmospheres in Europe. This approach is seen as an essential prerequisite to visioning the future of renewable energy support in Europe.

The first major topics of this thesis pave the way toward the status quo of electricity markets and support in Europe. First, the description of the historical development of electricity markets in Europe is given. It is accompanied by views on current objectives and tasks governing the near-future development of European electricity markets, as well as a section describing the main functionalities of a fully developed electricity market. The study then goes into available options of electricity tracking with the main focus on the history, functionality and legislation of guarantees of origin. This leads to the description of the development of renewable energy support in Europe. Also, detailed scheme design options, different national implementations and support volumes are described.

The knowledge base is then expanded by introducing the expected technological, financial and political developments relating to renewable generation within the EU. Cited publications describe and compare the extrapolation of current developments to proposed scenarios aimed to reach proposed long-term targets.

Later topics of this thesis use the established base to assess the adaptability of current support scheme types to predicted changes. Finally, the thesis also visions a preferable future framework for obtaining the ambitious targets set by the Community.

1.1. Research focus and questions

This thesis is trying to construct the premises for the renewable energy support framework required to reach the ambitious renewable energy targets of the EU. The discussion is bound to European level, often relying on larger theoretical frameworks and conclusions of more detailed research publications and reports. Some state-level examples are highlighted because of their pioneering effects and relevance on the whole support framework.

The main question of this research, presented below, thus sets an objective to roughly sketch the preferable future path of European renewable energy support.

> “How should the framework of renewable energy support change in the EU?”

In order to answer this primary question, a set of requirements need to be put in place in order to present the demands and restrictions for the future support mechanisms. A parallel evaluation of current support scheme types against the set of requirements is needed to determine the favourable option for renewable support.

> “What are the objectives and targets that need to be achieved within the future framework of renewable energy support?”

> “What are the restrictions and requirements for the future framework of renewable energy support?”

> “What are the theoretical capabilities of current support scheme types to fulfil the requirements for the future framework of renewable energy support?”

The above questions need to be built on a solid body of knowledge concerning the historical and trending features of the renewable energy support in Europe. It also has to be presented along with a description of the electricity markets, primary European objectives and other relevant mechanisms affecting the development of renewable energy sources.

> "What is the status quo of European electricity markets, and how have they evolved to that point?"
>
> "What is the status quo of European renewable energy support, and how has it evolved to that point?"
>
> "How are the elements of renewable energy support designed, and what is the underlying theory for them?"
>
> "What are the current support mechanism types in Europe, and which implications of these types are currently in use?"
>
> "What are the renewable electricity support volumes and costs in Europe?"
>
> "How is electricity tracked in Europe, and what are its historical connections to renewable energy support?"

In the following figure, the research questions are divided between three levels. Level 1 presents the main question of this thesis. Levels 2 and 3 provide the needed intermediate results and the required body of knowledge respectively.

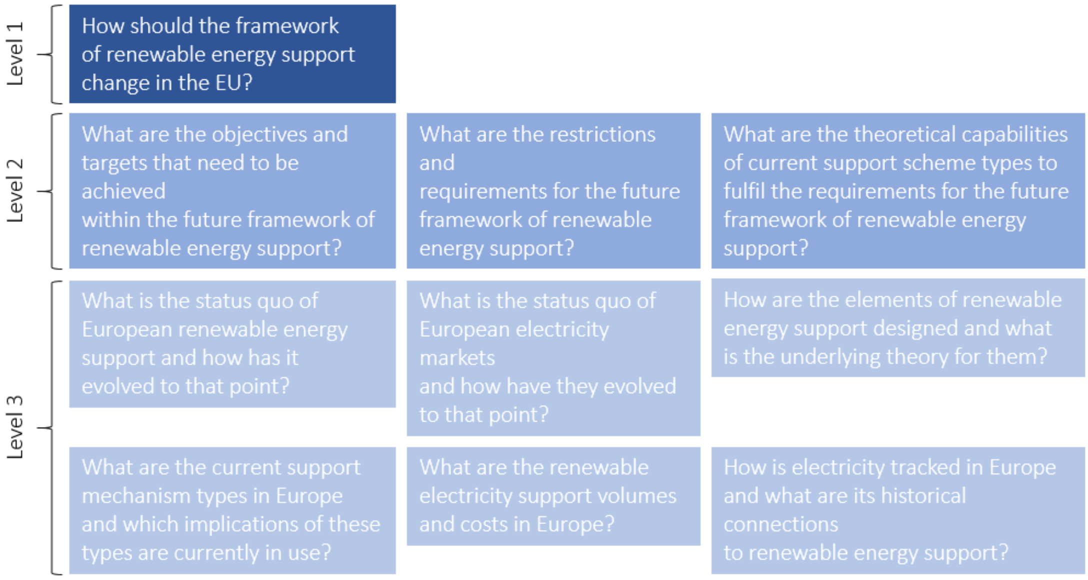

Figure 1.1: Hierarchical presentation of research questions

1.2. Research limitations – connection to the emissions trading scheme

This thesis will not assess or build upon the concept of the Emissions Trading Scheme (ETS). While it is obvious that renewable energy support affects the ETS and vice versa, the two mechanisms are assumed to coexist within own distinct frameworks. The same logic applies to a multitude of other policy structures affecting the decision-making processes in the EU. However, since scholars often suggest the abolition of renewable energy support as particularly counterproductive to emissions trading, it is well-grounded to justify the approach chosen in this study.

The mainstream argument that RES support policies undermine the effectiveness of the first-best policy of ETS only seems to be true in theoretical textbook models that introduce an isolated singular objective of climate protection. The situation is quite different in models resembling real-life situations by applying public-choice perspective with multiple policy objectives and externalities. In these more complex models, the negative effect of RES support on the ETS is no longer that evident. (Gawel, et al., 2014)

RES subsidies can improve the effectiveness of the ETS by lowering the allowance price and abatement costs, making a tighter emission cap negotiable. Supporting renewables may further increase the overall efficiency of climate and energy policy when the larger array of policy goals, e.g. security of supply and replacement of nuclear power, are considered. Thus, RES support schemes can provide benefits beyond the mitigation of climate change, and should therefore be introduced parallel to the emissions trading. (Lehmann & Gawel, 2013) (Gawel, et al., 2014)

1.3. Focal company – Grexel Systems Ltd.

This study is sponsored and facilitated by Grexel Systems Ltd. Grexel is a Finnish company providing core business infrastructure solutions and services for green commodity markets and environmental banking. Founded in 2001, Grexel has over 50 years of cumulative experience with the energy certificate markets and central certificate registries. Grexel is currently providing certificate registry services and support to nine European countries, covering registries for disclosure and support purposes. The company also has a strong position in regulatory and market engineering, helping the relevant authorities in different regions to best design their green energy markets.

2. Development of the European electricity markets

2.1. Historical context

Until recent decades, electricity in Europe has mainly been produced by vertically integrated state-owned monopolies. (Meesus, et al., 2005) The main attributes of such system are the lack of competition and consumer choice. Typically, separate franchise areas of operation for vertically and horizontally integrated entities were formed – usually mandated in law. While large-scale production and consumption were made possible by electricity systems of strong monopolies, their operation also created serious ecological and social problems. During the last decade, the shortcomings of vertically-integrated monopolies have become evident in economies with relatively large and mature electricity supply industries. (Trevino, 2008)

2.2. Paradigm shift and unbundling

The development of European regulatory framework, evolving from mere principles toward more detailed regulation, can roughly be divided into three phases. The first two periods focused on the market liberalisation, initially for industrial customers and later for others as well. The more recent third phase has set out to form a working cross-border regulation. (Sioshansi, 2013)

Economic pressure to increase efficiency, advances in technology and the deregulation and development of competition in other infrastructural industries have contributed to the movement away from vertically-integrated monopoly structures toward more market-based structures. (Trevino, 2008) The publication of the 1995 Green Paper on energy policy (19 Jul, 1995) can be considered as the spark in creating a single competitive energy market for Europe. It stated that the main objective should be the removal of the remaining barriers to the free movement of goods and services, and further improvement of the system of undistorted competition (European Commission, 1995). It was followed by approved European directives prescribing the liberalisation process of energy markets. (Dorsman, et al., 2011)

The deregulation of the European electricity sector was launched with the adoption of Directive 96/92/EC (Internal Market in Electricity Directive) (19 Dec, 1996). The liberalisation process aimed at increasing efficiency, harmonising and reducing electricity prices, improving public services, cutting reserve production capacities, better use of resources, giving customers the right to choose their supplier and providing customers with better service. The directive also initiated the unbundling of electricity services previously provided by large monopolies. It became mandatory for integrated companies to keep separate accounts for transmission, distribution, other electricity-related activities and other non-electricity-related activities. The intention was to divide the electricity sector into four segments: generation, transmission, distribution and supply. Generation and supply would be open to competition parallel to remaining regulation and/or monopolies in transmission and distribution. Member states were also obligated to designate a competent and independent authority to settle disputes between market actors. (Trevino, 2008)

The Lisbon Strategy, originally set out by the Lisbon European Council of 23-24 March 2000, has played a significant role in European market liberalisation by preparing an agenda for the following years. (Dorsman, et al., 2011) It set a goal “to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion”. It also underlined that this goal could not be reached without improving the competitiveness of the energy markets (Dorsman, et al., 2011).

The Directive 2003/54/EC (23 Jun, 2003) and Regulation (EC) No 1228/2003 (26 Jun, 2003) set out to address main issues of network access, tarification, market power in electricity production and different degrees of market opening between Member States identified after ratification of Directive 96/92/EC. (Trevino, 2008) The contents of this second package can be seen to form two strong pillars of increasing independence of “system relevant” players like transmission system operators (TSOs), distribution system operators (DSOs) and market regulators, as well as pointing market incentives to be consistent with market liberalisation. (Sioshansi, 2013) During the process, it became partly possible for consumers to choose their electricity supplier. This was enforced by the EU decision that from 2007 at the latest, all customers should be able to choose their electricity supplier. (Green, 2006)

Despite the laid-down design for cross-border markets, national transposition and the possibilities for enforcing regulation were disappointing and thus did not lead to a uniform market model in Europe. In general, the main area for improvement was found to be the lack of investment in interconnection capacity (Makkonen, et al., 2012). Other reasons include insufficient TSO independence, burdensome permission procedures for new transmission lines and the lack of economic incentives. (Sioshansi, 2013)

The updated European legislation required network segments (transmission and distribution) to be legally separated from competitive segments. In most member States, the TSO became a legally independent unit. For generation and supply segments, a strict separation was not required by the Directive. Thus, many market actors chose to reduce risk by re-integration movements like acquisitions and mergers. (Trevino, 2008) In some cases, these movements went to such an extent that they had a negative effect on the competition. (Lise, et al., 2007)

The Directive 2003/54/EC was repealed by the Directive 2009/72/EC (13 Jul, 2009), coming into force as a part of the third legislative package[1] for the European electricity markets. The third package introduced a new direction in legislative bundling by integrating the energy and environmental objectives of the EU through the use of market-based environmental and other measures. (Dorsman, et al., 2011) Member States had 18 months to transpose the package into national law.

The development of the European Internal Energy Market (IEM) is mainly guided by the standing third package. The third package emphasises and routes the objective toward a single market goal in European energy markets laid out by the previous legislative frameworks (Dorsman, et al., 2011), as well as binds the market objectives to the environmental guidelines.

It also underlines the need to put the single market project back on track as an essential prerequisite to competitiveness, tackling climate change, security of supply and overall well-being in Europe as was communicated by the European Commission already in 2007 (European Commission, 2007).

2.3. Towards a single electricity market

The idea of an internal market for electricity has long roots in history. According to the Single European Act strategy of Commission President Jacques Delors signed in 1986, the concept should have been implemented already in 1992. (Glachant & Ruester, 2014) This can now be seen as slightly optimistic.

[1] Directive 2009/72/EC 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC
Directive 2009/73/EC of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC
Regulation (EC) No 713/2009 of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators
Regulation (EC) No 714/2009 of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003
Regulation (EC) No 715/2009 of 13 July 2009 on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005

The completion of a genuine Internal Energy Market (IEM) (for both electricity and gas) is one of the highest priorities of the European Union. The IEM is planned to greatly contribute to European competitiveness by allowing broader access to safe, secure, sustainable and affordable energy. The existence of a competitive IEM would also give European consumers a possibility to choose between different electricity suppliers, and would allow all suppliers, big and small, to access the common market. This holds especially high value for small suppliers and those investing in renewable energy sources. A truly integrated market would contribute to diversification and thus security of supply, as well as development of renewable energy sources and a framework within which the emissions trading system could function properly. Cross-border trade, in particular via implicit auctions, would also balance the deficits and oversupply caused by intermittent renewable production (EUROPEX, 2014). The completion of the IEM is also widely recognised as a precondition for the cost effective achievement of European energy policy objectives (European Commission, 2014b).

Previous aspects are also underlined by the European Council in their paper "Conclusions on Energy" published on 4th Feb, 2011, which urges national regulators and transmission system operators to step up their work on market coupling and guidelines. (European Council, 2011)

A recent study by Booz&Co. et al. assesses benefits of integrated markets in electricity in the EU by constructing different development scenarios for two different timeframes. For the first of two timeframes, from 2004 to 2014, the estimate of the potential value of market coupling would be €4 bn per year. For the second timeframe, from 2015 to 2030, multiple scenarios are presented. Integrating the market would result in the largest benefits, €12,5 bn to €40 bn per year by 2030. However, if national security of supply is reached instead, the benefits vary from €3 bn to € 7,5 bn per year, although sharing balancing reserves would result in additional benefit of €0,3 bn to €0,5 bn per year. It is noticeable that Booz&Co. et al. predict benefits up to €30 bn per year for the second timeframe if a true common market for renewable energy exists. (Booz & Company, 2013)

Sencar et al. suggest in their article that market integration brings benefits, but if applied has to be accompanied by functioning balancing markets and, in the case of electricity, non-distortive capacity remuneration mechanisms. The article also notices that even currently, cross-border infrastructure could be used more efficiently at several inter-connectors, and that barriers, like end-user price regulation, to entry still exist. (Sencar, et al., 2014)

Glachant et al. raise many valid points concerning the slow progress over the decades in integrating European electricity markets and lists many problems still acute today. One of the large challenges is the need to adapt market design and network regulation to fast and often unanticipated developments. Equally important is to address the danger of re-fragmenting the European market due to uncoordinated national initiatives e.g. the diverse renewable support schemes that have resulted in effective but market-distorting subsidies. (Glachant & Ruester, 2014) Supplementing the previous, Lowe (as well as the European Commission) has stressed that any public intervention that is ill-designed and lacking a proper coordination at the European level risks being counterproductive and can distort the functioning of the IEM. (Lowe, 2011)

2.3.1. Electricity Regional Initiatives

The development of the IEM is largely in the hands of the Agency for the Cooperation of Energy Regulators (ACER). ACER's main aim is to complete the internal markets for electricity and gas. Although the responsibilities are in in the Agency's hands, it operates under political mandates that may from time to time change. Regulation (EC) No 713/2009 of the European Parliament and of the Council (13th Jul, 2009) established ACER with the aim of exercising at Community level the tasks performed by the Member States' regulatory authorities (European Parliament and Council, 2009c). Moreover, it incorporates establishment of the European Network for Transmission System Operators (ENTSO-E), which promotes the development of common commercial and technical codes and security standards (Glachant & Ruester, 2014). Integration of European electricity markets is implemented in practice through ACER's Electricity Regional Initiatives (ERIs), which were first launched by ACER's predecessor, European Regulators Group for Electricity and Gas (ERGEG), in 2006. ERGEG originally aimed at voluntarily involving National Regulatory Authorities (NRAs), Transmission System Operators (TSOs) and other stakeholders to advance integration at the regional level as a step towards the creation of an IEM. After taking over the cooperation responsibilities, ACER has now introduced a common vision for the completion of the IEM in electricity by 2014: electricity markets across Europe must share a set of common features and be linked by efficient management of interconnection capacities. In order to achieve this, Capacity Allocation and Congestion Management (CACM) and Balancing have been identified as priority areas.

Under ACER's ERI process, the NRAs have produced an EU Energy Work Plan for 2011-2014 based on clear, commonly agreed objectives and milestones. The work plan presents four cross-regional roadmaps focusing on the implementation of the target models for CACM across Europe. The work plan also provides each market region[2], defined within the ERI, a regional roadmap to complement and detail the cross-regional roadmaps, while also focusing on other important dimensions for the completion of the IEM. (ACER Coordination Group for Electricity Regional Initiatives, 2014)

ACER has, in its Regional Initiatives Status Review Report 2013, assessed the objectives laid down by the work plan to be ambitious but still attainable. (ACER, 2014)

3. Structure of electricity markets

Liberalization of the electricity industry has created a need for organised markets. Two types of markets have merged to meet this demand: power pools and power exchanges. The main difference between these two is that a power pool is a public initiative and participation is mandatory for regional producers and suppliers. A power exchange on the other hand is a private initiative and participation is voluntary, often existing side-by-side with bilateral, "over-the-counter", contracts. (Klimscheffskij, 2011)

3.1. Price formation and merit order

Most electricity markets work on a day-ahead basis. This basically means that electricity suppliers participating in the exchange have to submit their price-supply curves for each hour of the next day to the exchange authority. Respectively, electricity buyers have to submit their price-demand curves for the day ahead. Exchange authority then aggregates all individual submitted curves and determines an equilibrium price for each hour of the following day. This is called the electricity spot price. (Trevino, 2008)

[2] ERI defined regions: Baltic, Central-East, Central-South, Central-West, France-UK-Ireland, Northern, South-West

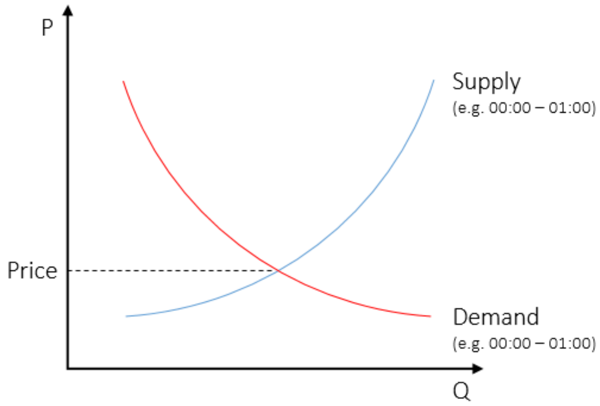

Figure 3.1: Purchase and sales bids are (e.g. hourly) aggregated to determine electricity spot price

Power producers use the short-term marginal cost of their power plants as their bidding price. This leads to a situation where the equilibrium price (or spot price) is the short-term marginal cost of the most expensive participating electricity producer during a particular hour. This leaves other operating producers with a short-term marginal profit. (Klimscheffskij, 2011) It thus follows that the order of utilising power plants for daily production is determined by the economic equilibrium of supply and demand (Nord Pool Spot AS, 2009). The system can be presented as a merit order curve where available capacity with short-term marginal prices lower than the hourly spot price are used to generate the required volume of electricity (Cludius, et al., 2014). For the system to be fair for all market participants, all environmental damage costs of the power plants need to be included in their cost function (Klimscheffskij, 2011). Using the short-term marginal cost as a bid in the spot price formation also leads to renewable energy sources with minimal short-term costs, like wind and solar, being always deployed and included in the supply curve. This is often referred to as the merit order effect.

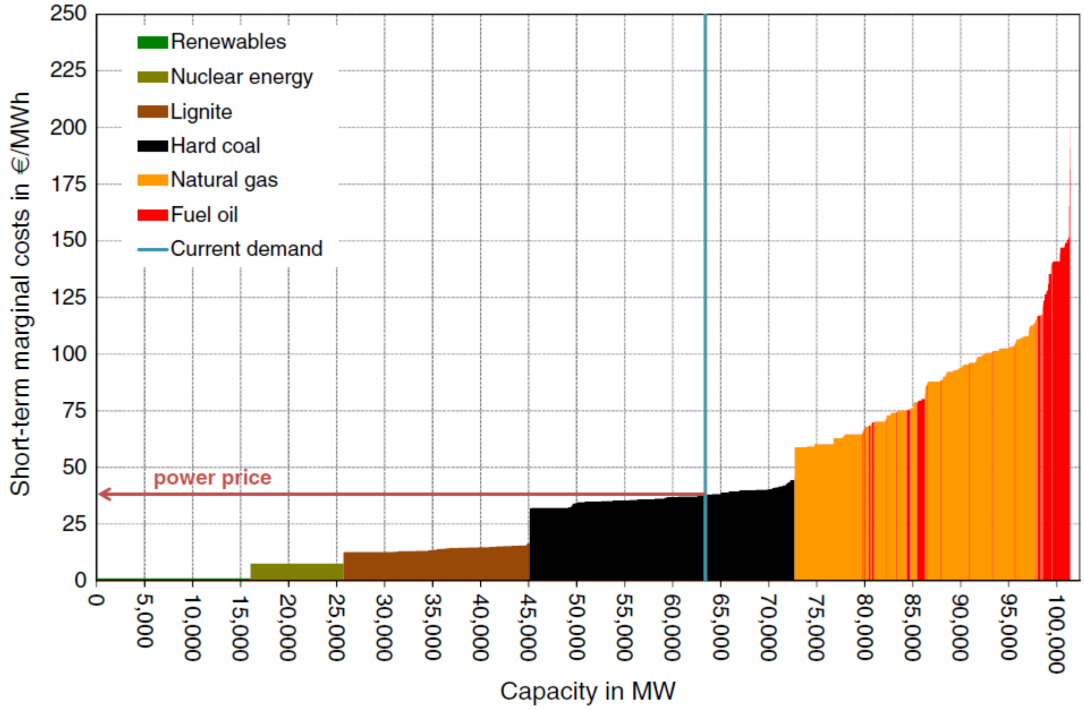

Figure 3.2: Illustration of German merit order curve (Cludius, et al., 2014)

Merit order effect, a.k.a. priority dispatch, has been studied by Oggioni et al. in order to determine its side effects on nodal pricing[3] and market coupling[4]. The findings show that priority dispatch has only a small effect on these mechanism as long as the fed volume is low. In contrast, as intermittent generation volume rises, the market coupling organisation collapses. However, the nodal pricing model continues to perform rather well. (Oggioni, et al., 2014) The European Wind Energy Association (EWEA) has shown a close correlation between high wind energy production and overall lower electricity prices due to the merit order effect (EWEA, 2010). Spiecker & Weber have estimated that intermittent renewables, like wind and solar, will reach a market share from 29% to 44% by 2050 (Spiecker & Weber, 2014).

Work by De Villemeur & Pineau has contributed to the conversation by providing evidence that electricity market integration (e.g. as planned by the EU) in different institutional

[3] Nodal Pricing is a method of determining prices in which market clearing prices are calculated for a number of locations on the transmission grid called nodes. (Phillips, 2004)
[4] Market coupling is the use of so-called implicit auctioning involving two or more power exchanges. (as defined by European Market Coupling Company GmbH http://www.marketcoupling.com/market-coupling/concept-of-market-coupling)

regimes generally calls for the adoption of marginal cost pricing in all jurisdictions[5]. (de Villemeur & Pineau, 2012)

3.2. Financial derivatives

To provide the market actors the possibility of price hedging and risk management, a commodity derivative exchange has been introduced to complement the physical electricity market (Klimscheffskij, 2011). In order to secure required cash flow, the commodities market allows market actors to make long-term purchase agreements (Nord Pool Spot AS, 2009). Common financial instruments used are futures, forwards, options and e.g. Contracts for Difference. There is usually no physical delivery of electricity associated with a financial contract. Technical restrictions are also not usually considered, and the day-ahead spot-price is used as a reference price. (NASDAQ OMX, 2014)

3.3. Balancing power

As can be expected, the day-ahead markets often fail to precisely predict the actual production and consumption of the hour of operation - the hour during which the power is delivered and consumed. This can be due to actual consumption of the supplier's customers deviating from the provided demand curve or e.g. a sudden breakdown of a producer's power plant. (Nord Pool Spot AS, 2009)

In order to maintain the balance in the market between the supplier's total trading and the supplier's customers' hourly consumption or between hourly demand and complete electricity production of consumers, electricity can be traded with the TSO, often referred to as the balancing power or as regulating power. Basically, the contracts made in the day-ahead market will hold during the hour of operation, and the deviations are settled with the TSO. (Nord Pool Spot AS, 2009)

Relating to supply side measures of balancing, the gap between production and consumption is addressed by presenting consumer-side options for flexibility. These are referred to as Demand Side Management (DSM). DSM promotes the interaction and responsiveness of the consumers. This promotes market efficiency as well as system operation and expansion. DSM also helps improve grid reliability and drives down peak loads, which helps reduce overall plant and capital cost investments. (Siano, 2014)

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[5] The study by de Villemeur & Pineau included two different jurisdictions: average cost pricing, and marginal cost pricing; and three different regimes: mixed-market structure in autarky, mixed-market structure with trade, and fully integrated markets.

Historically, DSM has covered utility's base load management and off-peak storage on the consumer side. Unlike the development in the US, DSM did not gain much ground in the EU. This can be explained by the lack of common framework[6] in the EU for such development to take place. Market liberalisation and deregulation in the 1990s further declined DSM's popularity among utilities. However, there has been renewed interest in DSM during the new millennia across the world as a result of climate change and energy security issues coming to the forefront of the political agenda. (Warren, 2014)

The EU has supported DSM mechanisms through directives[7], most notably the Energy Efficiency Directive (2012/27/EU), dictating consumer behaviour in electricity markets. These directives have helped to improve the monitoring of electricity consumption and increase the overall energy efficiency in Europe. (Warren, 2014)

Work by Feuerriegel & Neumann concludes that introducing DSM measures can have significant impacts on the structure and stability of electricity supplier costs, namely a full exploitation of DMS would decrease cost volatility by 7.74%, and the overall expenditures can be reduced by 3,52%. (Feuerriegel & Neumann, 2014)

3.4. Future actors

In future power systems, there will be a need for a new type of market participant, namely the aggregator. The aggregator enables demand response from smaller consumers due to load bundling capabilities, which can be offered in the wholesale electricity market. Aggregators will have to control multi-fuel, multi-location and multi-owned virtual power plants (VPPs) that combine power outputs from distributed electricity production. (Koliou, et al., 2014)

[6] As a reference, the US introduced common DSM mechanisms already in 1978 in *the National Energy Conservation Policy Act* and *the Public Utility Regulatory Policy Act* (PURPA) as part of *the National Energy Act*. (Warren, 2014)
[7] Smart Meter Rollout Directive (2009/72/EC), Energy Labelling Framework Directive (2010/30/EU), Ecodesign Framework Directive (2005/32/EC)

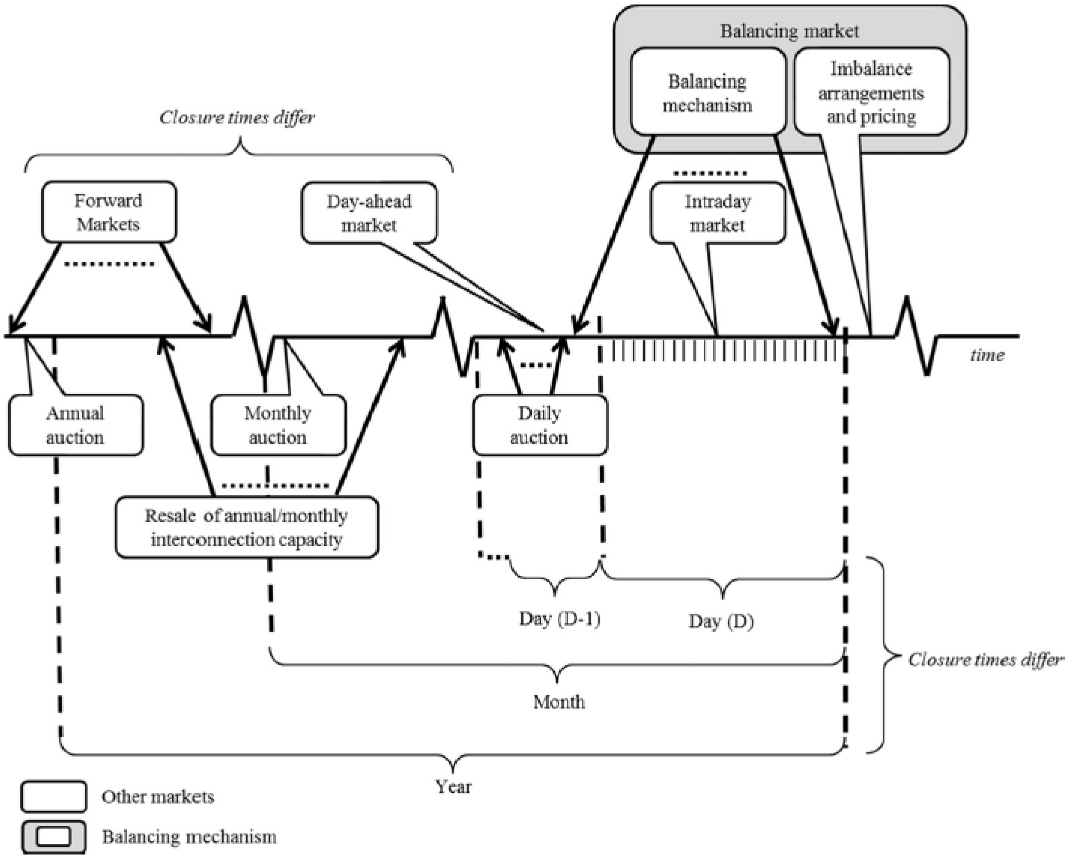

Figure 3.3: Time sequence of electricity market functionalities (Koliou, et al., 2014)

3.5. Renewable energy sources in electricity generation

REN21[8] has estimated that global final energy consumption in 2012 consisted of 78.4% fossil fuels, 19% renewables and 2.6% nuclear power. A later time estimate focusing on global electricity production in end-2013 gives a combined share of 77.9% for fossil and nuclear production, leaving renewables with 22.1%. (REN21, 2014)

In 2012, Europe reached a share of 23.5% of renewable energy in electricity generation. The historical development of the overall renewables share in EU28 countries is presented in the below figure. Figure 5.1: Share of renewable energy in % gross final energy consumption in 2012 compared to national 2020 targets presents the country-specific shares of renewable energy generation in overall energy consumption in 2012 as compared to the national binding 2020 targets.

[8] Renewable Energy Policy Network for the 21st Century

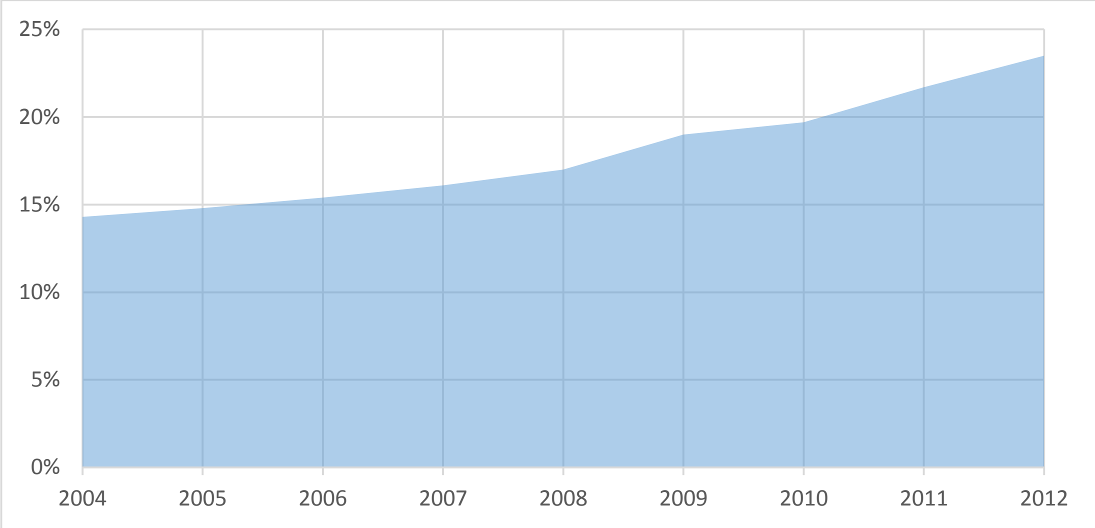

Figure 3.4: Share of energy from renewable sources in EU28 area (data from Eurostat nrg_ind_335a)

Trevino has pointed out that hydro (where available), coal and natural gas have attracted the most investments in deregulated markets because of their lower costs over the depreciation period. Large actors have also been able to make large investments in nuclear capacity, which has attractively low operation costs. Although renewable production has traditionally been the most expensive form of generation, it has expanded its share. This expansion is mainly due to the financial support schemes. (Trevino, 2008)

4. Electricity tracking

Electricity, regardless of technology, location, or time of generation, is by nature homogenous. Thus, after being fed into the grid, it is impossible to physically track the individual electrons or larger amounts of generated electricity. Lise et al. have described electricity tracking as "... a procedure to allocate electricity generation attributes to individual consumers or groups of consumers (such as all customers of a supply company or all customers of a specific electricity product)." (Lise, et al., 2007)

4.1. The need for electricity tracking

Highly developed European electricity markets and numerous Community and national level policies require relatively detailed allocation of electricity attributes, items of information related to the generation of a certain instance of electricity, on the level of electricity retailers or even groups of (or individual) consumers. In order to do this, attributes obtained at the point of generation of electricity must be allocated at an adequate level. (Timpe, 2007) Liberalisation of the European electricity markets has made it feasible for electricity producers and suppliers to differentiate in order to uphold their competitiveness. New opportunities have also arisen where the market can embrace a more significant role in reaching a higher share of sustainable generation and marketing of electricity. (Lise, et al., 2007)

Lise et al. have listed three main reasons for tracking generation attributes (Lise, et al., 2007):

- Proof of generation for a specific support scheme
- Proof of generation in a reporting scheme, in particular disclosure of generation attributes to the consumer
- Accounting for the national indicative targets for RES-E

Allocation of attributes for disclosure can be divided into implicit and explicit tracking mechanisms.

4.2. Implicit Tracking

Implicit tracking mechanisms use various statistics available to the supplier to determine a distribution of different sources of energy for a given network. A default data set of generation attributes from a group of producers is used to determine average energy source shares for a group of consumers. (Klimscheffskij, 2011) In this sense, implicit tracking is not an instrument of tracking at all, but a statistical process for dividing the available amount of generation attributes equally among a given set of consumers.

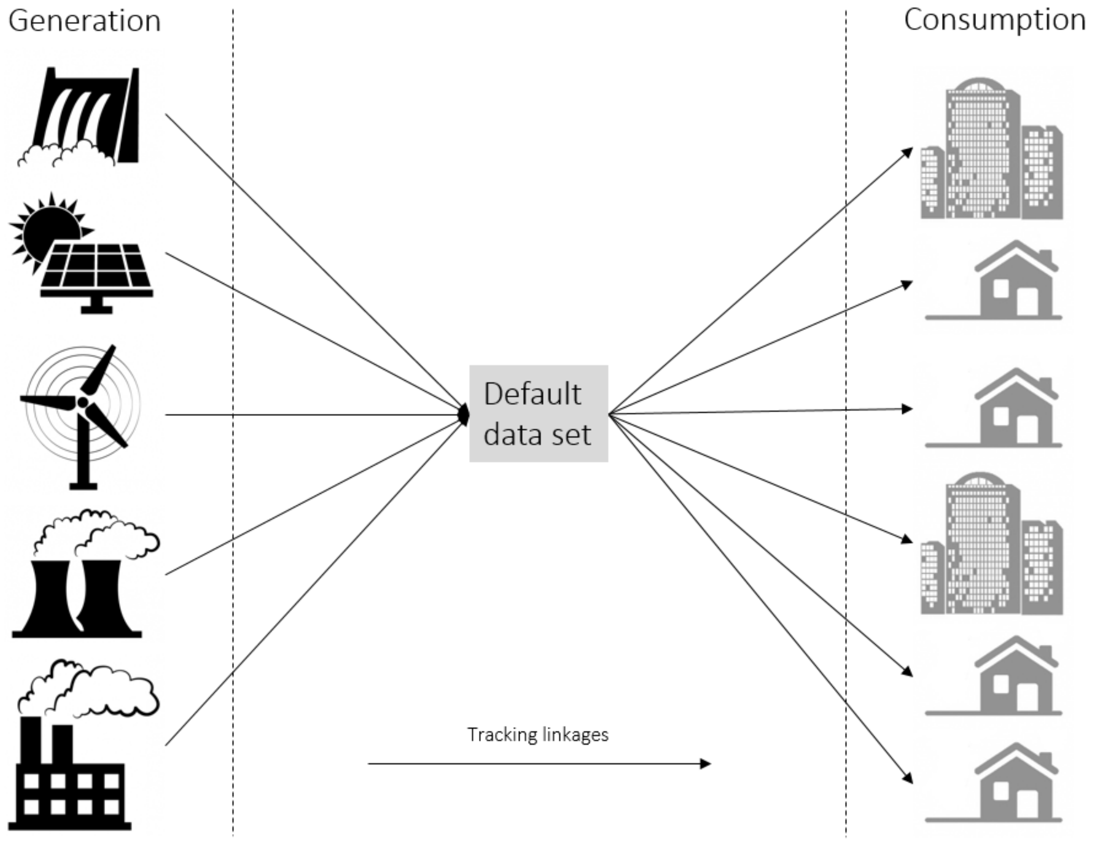

Figure 4.1: Implicit electricity tracking. All consumers share the average generation mix attributes. Based on (Timpe, 2007)

Implicit tracking, however, has a significant role in modern electricity disclosure systems in Europe. Implicit tracking, in the form of national residual mixes and the European attribute mix (EAM), is used to disclose untracked consumption on a national level. (RE-DISS II, 2014a) The figure below shows the amounts of tracked and untracked consumption in 2013 in European countries. The national residual mixes, calculated using national production figures and the EAM, are used to allocate production attributes to the untracked part of the generation.

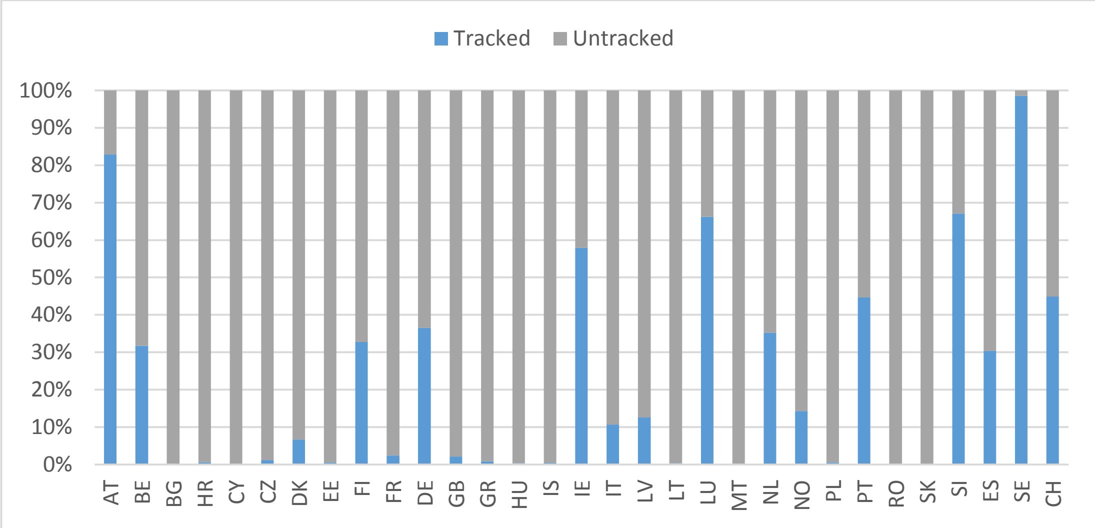

Figure 4.2: Tracked and untracked shares of electricity production in 2013 (RE-DISS II, 2014b)

4.3. Explicit tracking

Explicit tracking of electricity is essentially a mechanism for allocating generation attributes, created at the point of electricity generation, to the consumers. Explicit tracking can be further divided into linked and de-linked tracking of attributes, where tracked attributes are either bundled with contracts of physical electricity procurement or not. (Timpe, 2007)

4.3.1. Linked explicit tracking

Linked explicit tracking, or contract based tracking (CBT), embodies the idea of trading generation attributes bundled with (linked to) physical electricity procurement contracts. Linked explicit tracking can be applied ex-ante ("before the event") or ex-post ("after the event") the physical electricity exchange. In an ex-ante version, the attributes are bundled with actual electricity contracts before the event of trade. In the ex-post version, the attributes are allocated according to contracts after trade has ended. Linked explicit tracking is quite cheap and relatively easy to implement in systems with long-term bilateral contracts. However, in the case of multiple trade cycles before delivering the electricity to final consumer or in cases of changing bilateral contracts, the CBT method becomes increasingly complex and vulnerable. (Klimscheffskij, 2011) Additionally, CBT (here ex-ante CBT) is unfit to be used in current power exchanges, as tradable electricity would have to be differentiated instead of electricity trade as a single-priced commodity. (Lise, et al., 2007)

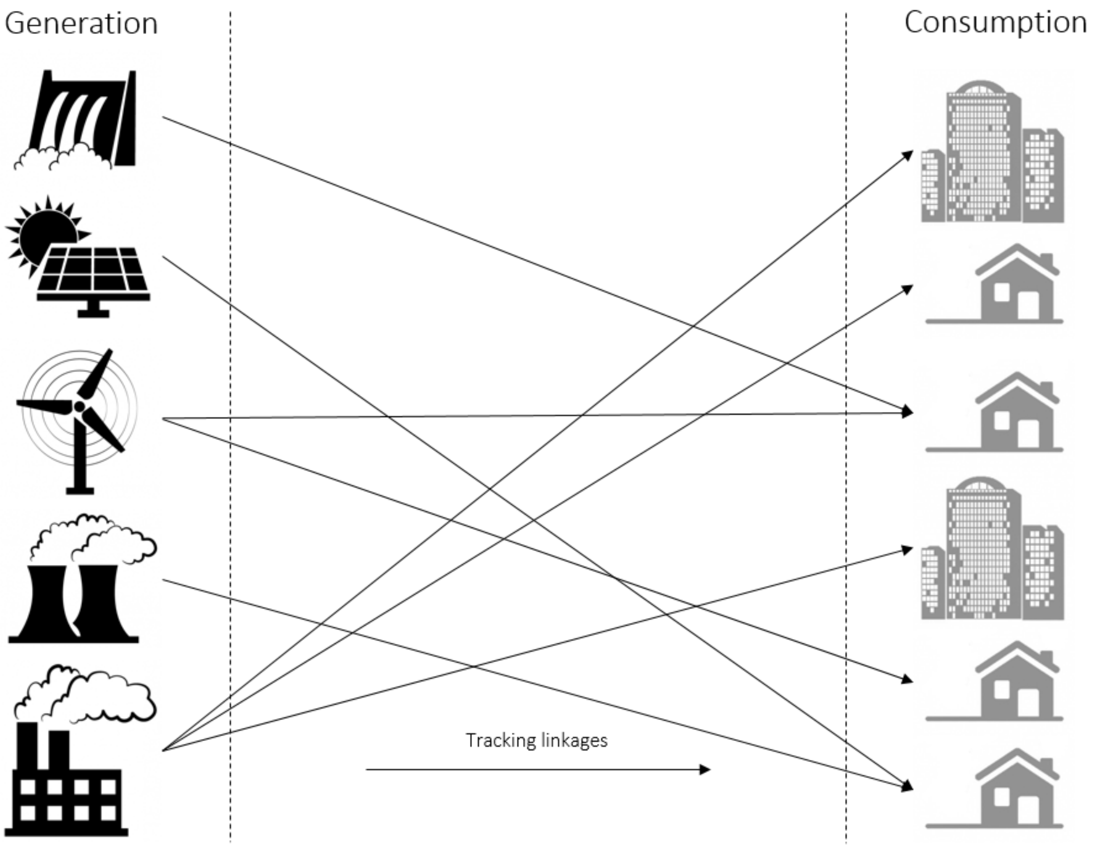

Figure 4.3: Linked explicit tracking (contract based tracking). Generation attributes are bundled with electricity contracts. Based on (Timpe, 2007)

4.3.2. De-linked explicit tracking

De-linked explicit tracking revolves around the idea that generation attributes do not have to be attached to physical electricity trade, but a separate market for generation attributes can be introduced. The trade is implemented via standardised certificates issued for each amount of generated electricity and holding a predetermined set of information. Certificates are first issued to the accounts owned by electricity producers according to actual metered electricity production. Producers then sell it independently from the generated electricity. Certificates are ultimately bought and used by electricity suppliers or consumers. They cancel the certificates to claim the origin of electricity consumed or sold. (Klimscheffskij, 2011) It is essential to notice that within a de-linked explicit tracking scheme, the attributes of a certificate are not necessarily allocated to the consumption of the physical electricity for which the certificate was issued for.

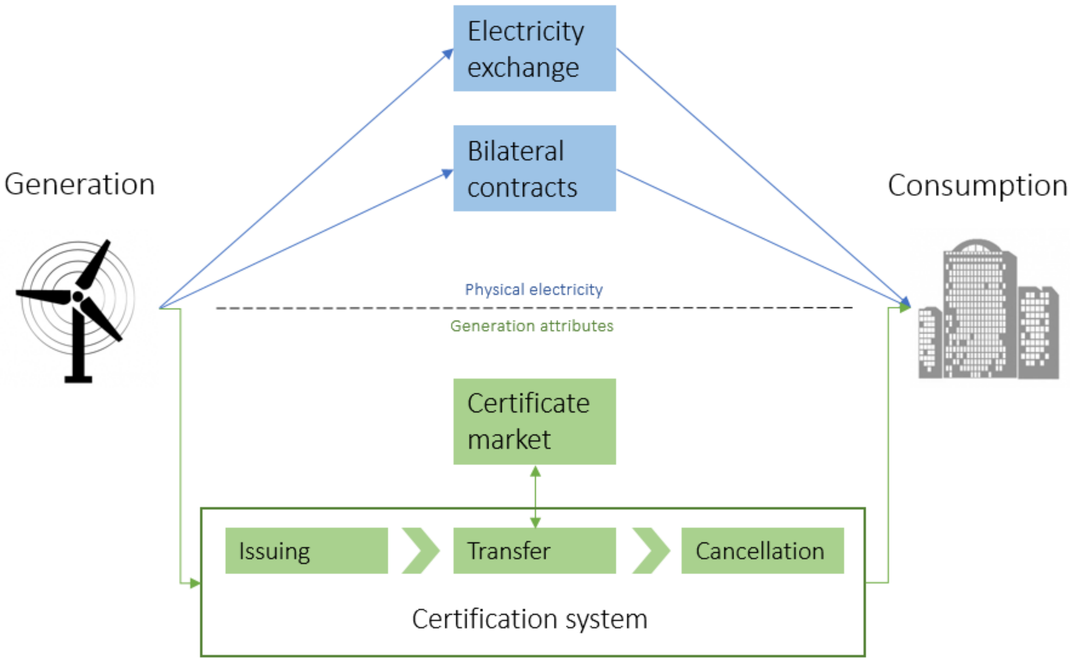

Figure 4.4: De-linked explicit tracking. Electricity and generation attributes are traded on separate markets. Based on (Klimscheffskij, 2011) and (Timpe, 2007)

Since in a de-linked explicit tracking system the certificate market is separated from the electricity market, the mechanism is very independent and robust against changes in physical market. Compliance with a system of power exchange and bilateral contracts is also good, as certificates do not have to follow electricity procurement contracts, but can be moved independently. Development of electricity markets with separation between production and supply supports the use of de-linked explicit tracking mechanisms (Klimscheffskij, 2011).

Overall complexity of the system can be considered a downside of the de-linked system, as it is less comprehensible to the average consumer (Klimscheffskij, 2011). The relationship between the de-linked attributes and the physical electricity can be challenging to communicate, especially since the allocation of attributes to an amount of consumed electricity can occur after a significant time has passed from the generation of relating physical electricity. (Aasen, et al., 2010)

In its Directive 2009/28/EC, the European Union has declared Guarantees of Origin (GOs) as the official (de-linked) tracking mechanism of energy. (European Parliament and Council, 2009a)

4.4. Guarantee of Origin

"Guarantee of Origin means an electronic document which has the sole function of providing proof to a final customer that a given share or quantity of energy was produced from renewable sources as required by Article 3(6) of Directive 2003/54/EC"

- Directive 2009/28/EC

The above quotation from Directive 2009/28/EC embodies the main concept of a Guarantee of Origin (GO). In general, the purpose of a GO is to inform the consumer about the relevant information on the electricity they purchase, or, in other words, ensure the ownership of certain attributes relating to purchased electricity. The use of GOs for disclosure purposes is based on a voluntary market that is monitored by nationally appointed authorities (Raadal, 2010). GOs are part of the EU disclosure scheme on electricity for which the following goals are specified (Aasen, et al., 2010):

- Ensuring market transparency by providing relevant stakeholders easy and open access to reliable information
- Providing product transparency to electricity consumers
- Enabling and educating informed consumers by providing comparable information about electricity suppliers' generation attributes
- Contributing to a more secure and sustainable electricity system

4.4.1. Definition of GOs

In addition to the definition given above, the Directive 2009/28/EC sets a common framework on which the European GO system is based. The following collection of GO requirements, based on the Renewables Directive 2009/28/EC, gives an overview of the Community level premises for the GO.

The most important characteristics of a GO are (European Parliament and Council, 2009a):

- One GO shall be of a standard size of 1 MWh (2009/28/EC, Art. 15(2))
- GOs are to be issued, transferred and cancelled electronically (2009/28/EC, Art. 15(5))
- Usage of GOs shall take place no later than 12 months from the production of the electricity unit they refer to (2009/28/EC, Art. 15(3))
- "A guarantee of origin can be transferred independently of the energy source to which it relates to, from one holder to another" (2009/28/EC, 0 (52))

- GOs issued for an electricity producer will be deducted from the attribute mix it delivers to its customers (2009/28/EC, Art. 15(8))

In order to secure the reliability of tracking, Member States must comply with following statements (European Parliament and Council, 2009a):

- Member States must have designated Competent Bodies to supervise the issuance, transfer and cancellation of GOs (2009/28/EC, Art. 15(5))
- Member States have to establish reliable, transparent and fraud-resistant procedures for GOs (2009/28/EC, Art. 15(5))
- "Member States shall ensure that the same unit of energy from renewable sources is taken into account only once" (2009/28/EC, Art. 15 (2))
- Member States can refuse to recognise a GO from another Member State under "well-founded doubts about its accuracy" (2009/28/EC, Art. 15(9))

The Directive also clarifies the relationship between GOs and renewable energy targets and support schemes (European Parliament and Council, 2009a):

- "Member States may provide that no support be granted to a producer when that producer receives a guarantee of origin for the same production of energy from renewable sources" (2009/28/EC, Art. 15(2))
- GOs are not a support mechanism[9] and "it is important to distinguish between green certificates used for support schemes and guarantees of origin" (2009/28/EC, 0(52))
- GOs have no function in terms of compliance with national renewable energy targets or target cooperation mechanisms (2009/28/EC, Art. 15(2))

Reliable disclosure systems for Europe (RE-DISS), an Intelligent Europe Programme project of the European Union, has published a RE-DISS Best Practices document, giving a detailed description on how GOs and disclosure systems should be implemented in practice. (RE-DISS II, 2012)

4.4.2. The Association of Issuing Bodies

Development of the international energy certificate schemes has largely been in the hands of the Association of Issuing Bodies (AIB). AIB is a non-profit scientific association registered by the laws of Belgium and having administrative offices in the UK. The over a decade-old

[9] It should however be noticed that the revenue received from selling GOs benefits renewable producers, although this income has been relatively small in the past. (Klimscheffskij, 2011)

association has published and maintains the European Energy Certification System (EECS), a standard ensuring that each EECS certificate is uniquely identifiable, transferable and therefore tradable, and contains standard information on the source of the energy and its method of production. (AIB, 2014d) (AIB, 2014c)

In 2013, AIB had a total of 19 members representing 16 European countries. As of 23rd May 2014, the 20th member, Croatia, was accepted by the general meeting held in Rome.

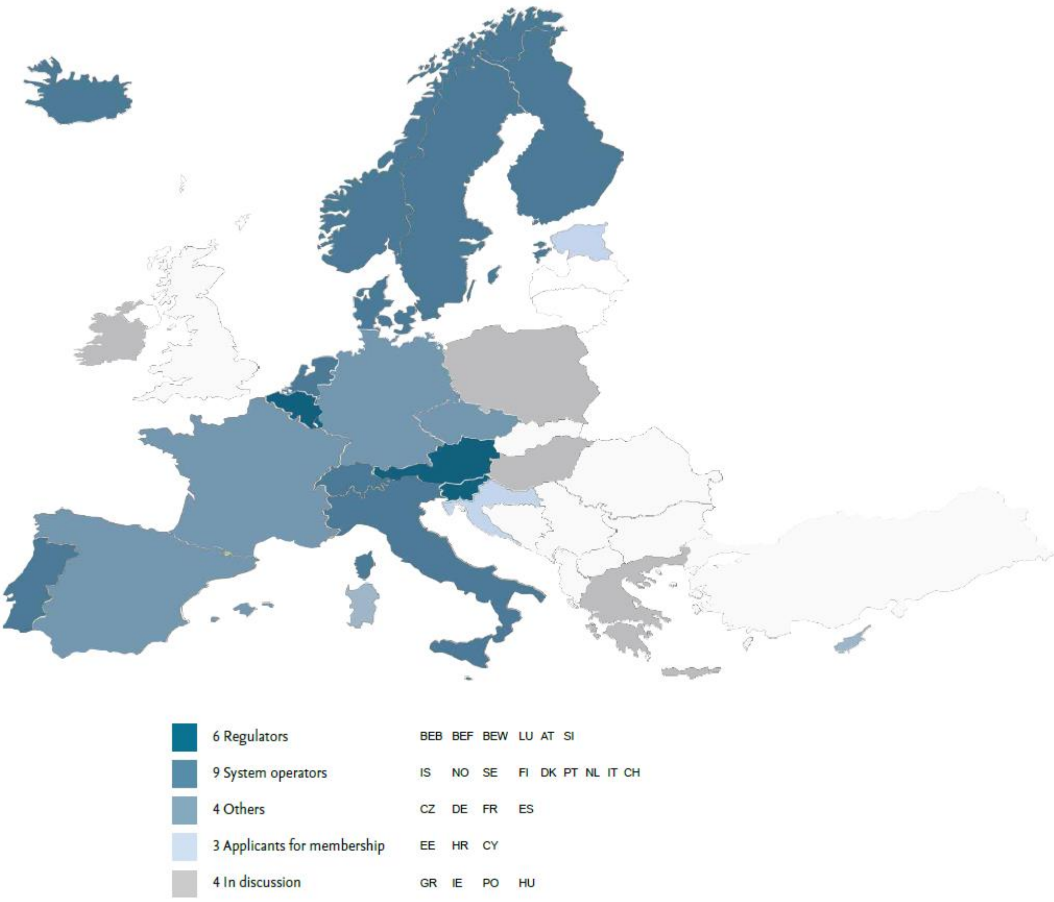

Figure 4.5: Members of AIB (AIB, 2014b) (Notice that since May 2014 Croatia (HR) has changed from an applicant to a member)

4.4.3. The legislative history of GOs

The Directive 2009/28/EC provides a relatively clear and simple definition for Guarantees of Origin (GOs). However, the process leading to the current legislation was far from simple (Nilsson, et al., 2009). The concept of GOs has swung from being a flexible mechanism for Member States to attain their binding targets in RES production, to embodying a harmonised EU-wide renewable energy support scheme (Klimscheffskij, 2011), only to end up as a completely separate system having little to do with either of the aforementioned purposes.

This chapter aims at giving a brief overview of the process leading to the current status of GOs, and attempts to approach this development through different points of view.

GOs were first introduced in Directive 2001/77/EC parallel to the national indicative renewable energy targets for year 2010. In the Directive 2001/77/EC, GOs served the purpose of disclosure. However, the directive failed to establish a link between the disclosure purposes of GOs and the national targets, which resulted in uncoordinated implementations of GO systems for disclosure and very different specifications for GOs in Member States. (Nilsson, et al., 2009)

Directive 2001/77/EC introduced an option of Tradable Green Certificates (TGCs) as a mechanism of support for renewables on a national level (European Parliament and Council, 2001). The idea stems from a White paper (European Commission, 1997) and the following staff working paper (1999) with the Commissions demand for a harmonised support for renewable electricity through a mechanism that is compatible with the concept of an internal electricity market. Although a TGC system was introduced in 2001, it was too early for it to evolve into a common support scheme, and the idea of European support was not widely accepted. (Nilsson, et al., 2009)

During the following years, there was much debate over the efficiency and potential of competing feed-in tariffs (FITs) and TGCs as support mechanisms for renewable energy. The economic theory and Community level goal toward a common electricity market supported the adoption of a TGC system (Nilsson, et al., 2009). However, supporters of FIT were convinced of the capability of set tariffs to deliver large amount of RES with the combined possibility to allocate support according to specific technological needs (Fouguet & Johansson, 2008). FIT supporters also accused TGC systems in failing to sustainably support a large variety of technologies and having a tendency to support large market actors with substantial amounts of support-eligible capacity. This effect would be amplified if this capacity would gain windfall profits – a volume of support exceeding the amount required for competitiveness due to setting the level of support according to long-term marginal costs of least developed (most expensive) technologies. (Jacobsson, et al., 2009)

After long obscurity left by the 2001 directive, in January 2008, the Commission proposed a binding target of 20% renewable share in overall Community energy consumption accompanied by binding national targets. In the initial proposal, Commission stated that issuing of GOs would be mandatory for electricity generation from renewable sources, and that GOs would be the cost-efficient mechanism for Member States to fulfil their targets. (Nilsson, et al., 2009)

The proposal was, however, burdened with a number of prerequisites and qualifications as a result of intense advocacy efforts on behalf of Member States and other interest groups who were highly concerned with the compatibility of the proposed system with by then common and developed FIT schemes. Other such concerns were the ability to continue supporting technologies that were not yet competitive as well as an overall uncertainty of the legal situation after the deployment of the GO "product". There was also a common fear of unbearably high certificate prices. (Toke, 2008) The proposal received even more negative feedback for its triple function – disclosure, support and target compatibility. Multiple functions were deemed as problematic for legislation and incompatible with existing national support schemes. (Nilsson, et al., 2009)

The proposal was further amended by a suggestion that target accounting would be fully based on energy statistics and would allow transfer of renewable energy only through tradable Transfer Accounting Certificates[10] (TACs) separated from GOs (Klimscheffskij, 2011). However, TACs were rejected in another amendment, by governments of Germany, Poland and the UK, because of feared administrative burden. With the amendment, target compliance via the use of certificates was discarded. (Klessmann, 2009)

During the second half of year 2008, the time for finding a solution for target compliance and RES support was running out due to the upcoming 2009 elections. The busy time included intense lobbying from both sides of the proposed support and compliance mechanisms, but in the end the role of GOs in target compliance was rejected in the December 2008 Directive proposal. (Nilsson, et al., 2009) GOs were clearly separated from support and target compliance mechanisms and defined as means of tracking electricity generation attributes. (Klimscheffskij, 2011)

The reasons for the rejection of proposed roles are up for speculation. However, it seems probable that the resistance toward involving GOs in flexible target compliance is partly due to the estimated rise in GO prices if GOs are allowed to be used in national targets. Rising prices would undermine the original purpose of disclosure by becoming too expensive for consumers to procure. (Klimscheffskij, 2011) High prices and a supposed lack of technological

[10] In addition to TACs seven other flexibility mechanisms were proposed for target compliance, four of which were rejected. (Klimscheffskij, 2011)

flexibility also contribute to resistance met by certificate systems from environmental NGOs, although the resistance was not uniform. Another aspect leading to the abandoning of the original proposal is the pronounced role of national security of supply. European dependence on foreign energy and high motivation of governments to maintain control over national energy sectors contributes more to the existing national tariff systems than to a harmonised pan-European approach with decentralised market mechanisms in control. (Nilsson, et al., 2009)

4.4.4. Functioning and life-cycle of GOs

National implementations of GO schemes are developed in accordance with the requirements of the Directive 2009/28/EC and maintained by national market enablers – often appointed by the government. These are the Competent Body (CB), mandated to facilitate the GO system in a domain[11], and other market enablers, like the Issuing Body (IB), Registry Operator (RO), Accreditation Bodies and Data Collectors. (Timpe, 2007) Market actors are private parties operating in GO markets in order to support renewable development or for pure financial gain. (Klimscheffskij, 2011)

Currently, GO systems, besides providing disclosure possibility, offer Member States information and experience in designing and implementing support schemes, creating more detailed reports and statistics on renewable energy development, monitoring trends in renewable energy adoption and accurately defining requirements for renewable electricity. (Jansen, 2005)

In short, a GO's lifecycle starts with the issuing of one GO for each MWh of generated renewable energy. GOs can be transferred through interconnected registries in different domains during their lifetime until finally cancelled for electricity disclosure by a market actor, who in most cases is the beneficiary.

An amount of GOs equal to the amount of verified electricity[12] generation in MWhs is issued by the IB to the account of the electricity producer. Only one GO can be issued for 1 MWh of electricity production. Each domain has one designated IB that is responsible for issuing GOs

[11] When discussing market regions for GOs it is useful to use the concept of a domain instead of a country since a country can have multiple domains (e.g. Belgium) with different market enablers.
[12] The Directive 2009/28/EC requires GOs to be issued for renewable generation. However in some countries GOs are also issued for other types of energy, namely fossil and nuclear.

for electricity producers, but usually this task is carried out by the CB. The IB is usually the electricity market regulator or the relevant TSO. (Timpe, 2007)

Once issued, the GO is transferrable/tradable for its entire lifetime. GOs can be transferred inside a domain or imported/exported with other domains. All GO transactions[13] take place in a domain-specific central registry provided by domain's RO.

As stated before, GOs are digital documents holding information about electricity generation attributes. Thus, they are ultimately used to allocate these attributes to sold or purchased electricity. When a GO is cancelled, it is removed from the circulation and its attributes are used for a named beneficiary. The main cancellers are the electricity suppliers who use GOs to construct different products, e.g. electricity from wind power, for their customers. Alternatively, they can use GOs to make their entire supply mix "greener". Another group of GO cancellers are the non-power companies using GOs to green their electricity for marketing value. (Timpe, 2007)

GOs have a lifetime of 12 months, starting from the end of the relevant production period, within which the GO must be cancelled. Otherwise, the GO is expired and removed from the system.

A well-functioning disclosure system offers reliable information on generation attributes, such as energy source and environmental attributes, for cancelling parties. (Timpe, 2007)

[13] Issuing, transfer, cancellation, expiry and withdrawal

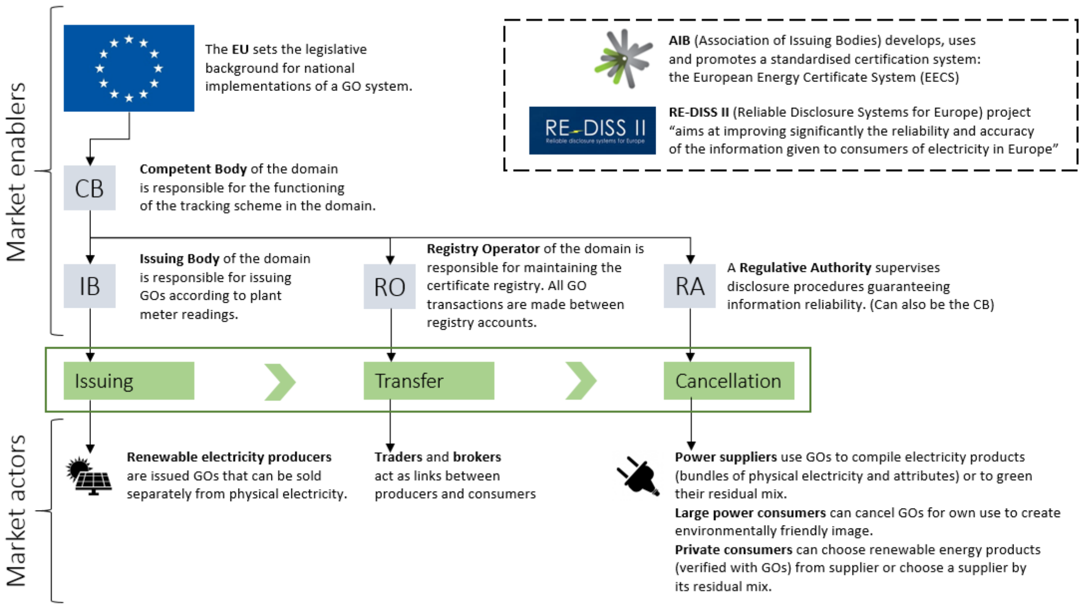

Figure 4.6: GO market enablers and actors. Based on (Klimscheffskij, 2011)

4.4.5. GO markets

Between 2001 and Q2 2014, a total amount of 1 954 495 374 GOs have been issued. This corresponds with around 1 954 TWh of renewable electricity generation. The development of GO volumes is presented in following figures. In Figure 4.7: Issuing and cancellation volumes of GOs 2001-2013, the issuing volumes for GOs were allocated to the electricity production year, whereas the cancellation volumes are allocated to the year in which the cancellation took place[14]. Transfer[15], export and import figures are allocated to transaction years.

[14] The approach was chosen to ensure maximal coverage of data. Most relevant parties report production year based issuing figures and transaction year based cancellation figures. Choosing a uniform allocation logic for both statistics would probably result in information loss.

[15] Referring here to an internal transfer

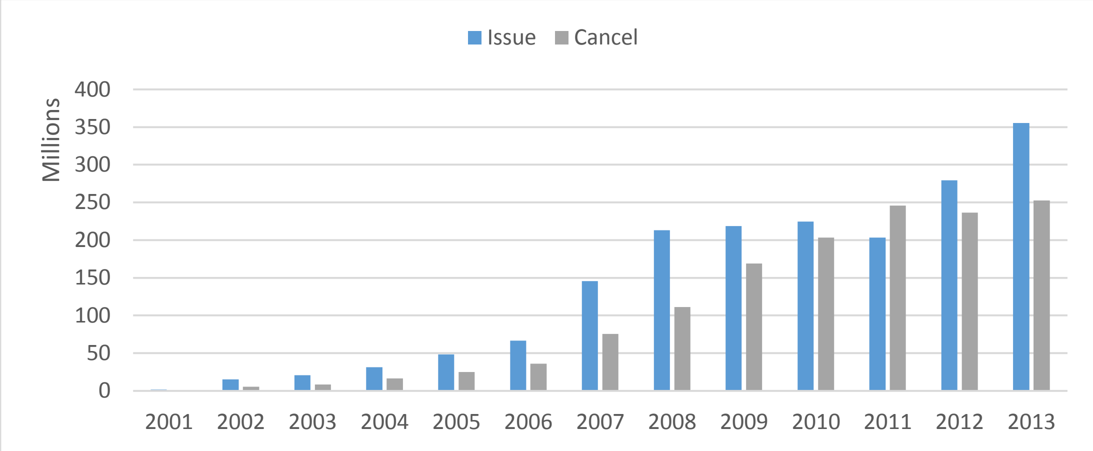

Figure 4.7: Issuing and cancellation volumes of GOs 2001-2013 (AIB, 2014a)

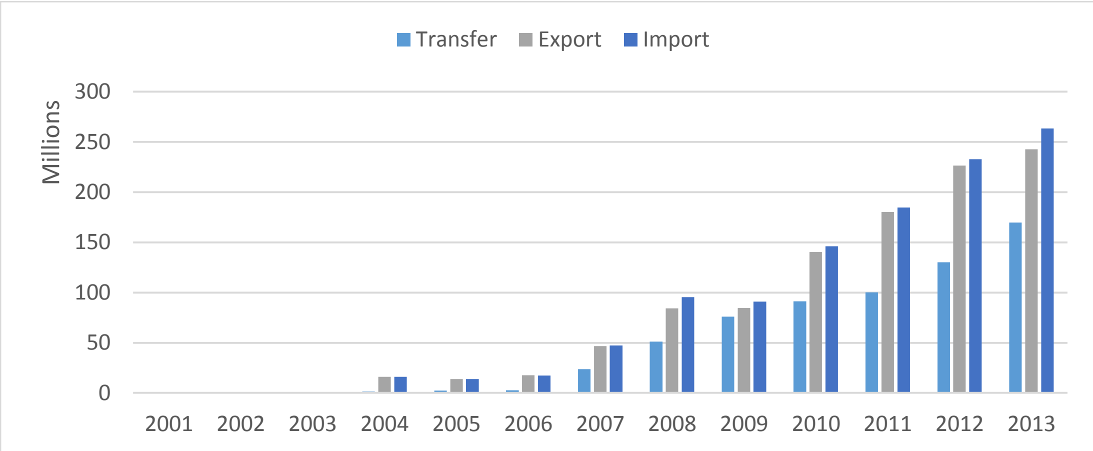

Figure 4.8: Transfer, export, and import volumes of GOs 2001-2013 (AIB, 2014a)

The above figures show that GO market growth has been rapid. Comparing figures for issuing and cancellation of GOs, it seems that although issuing gained wind quite early, the cancellation of GOs started to grow after some time of learning. When comparing internal transactions to import-export figures, it becomes clear that trade in GO markets is very international. More information about the international trade of GOs during recent years is shown in below figures.

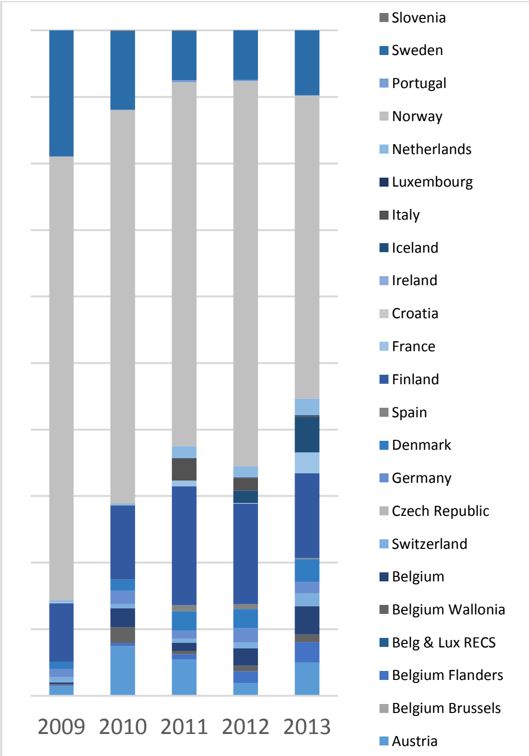

Figure 4.9: Distribution of GO export volumes between relevant countries 2009-2013 (AIB, 2014a)

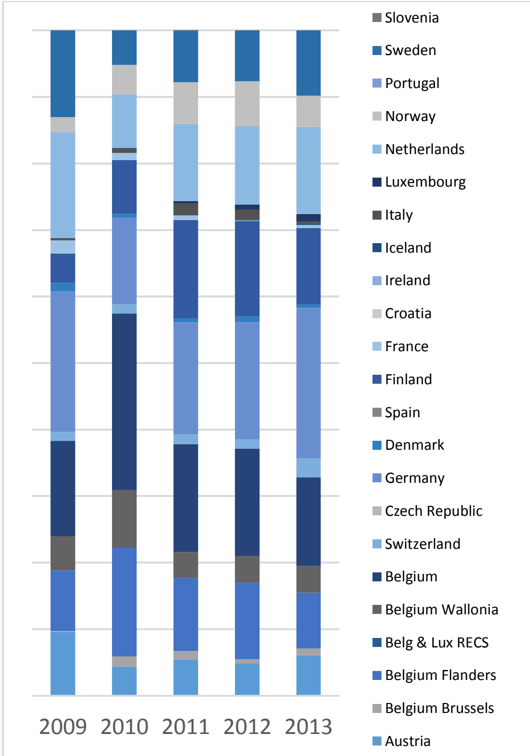

Figure 4.10: Distribution of GO import volumes between relevant countries 2009-2013 (AIB, 2014a)

Above figures show that historically, Norway has been the most active exporter of GOs, which is logical when accounting for the large share of renewables in electricity generation and the extensive hydro power capacity. The effect is, however, weakening due to market growth and new eligible capacity. On the import side, this kind of development is not observed, as import shares are quite evenly distributed.

GOs can be sold as specific products with attributes guaranteeing e.g. certain used technology or location. The price volatility between such products is extremely large. For example, the price of different products sold by a broker can vary from EUR 0.05 per MWh[16] up to EUR 11.00 per MWh[17]. EEX has also published data on GO price development during 2013. On the exchange, three different GO products are sold: Nordic hydro power (settlement price between EUR 0.001 and EUR 0.210), Alpine hydro power (settlement price between EUR 0.001 and EUR 1.050), and Northern continental Europe wind power (settlement price between EUR 0.001 and EUR 0.350). (EEX, 2014)

[16] Nordic Hydro HKN GO product for 2013 (price taken on 2014-08-07)
[17] Swiss Hydro HKN GO product for 2015 with naturemade star label (price taken on 2014-08-07)

5. Development of the European renewable electricity policy

5.1. Historical content

Renewable energy has been in the focus of European policies since the mid-90s. Support for development of renewable energy production was set in motion in 1995 by the European Commission's "White Paper on Energy". In 1997, it was followed by a more detailed "Energy for the Future: Renewable Sources of Energy – White Paper for a Community Strategy and Action Plan," which proposed a target of 12% of renewables in the European Union by the year 2010. This target was confirmed by the Directive 2001/77/EC, which introduced indicative targets for member states to collectively reach the 12% goal. (Fouguet & Johansson, 2008)

The two main approaches for the EU climate and energy regime have been setting targets as a mechanism to drive change, and a more profound drive to promote competition and limit state intervention. The 2008 Climate and Energy Package has been a flagship project for the first approach, and the wider concept of the Internal Energy Market has been a cornerstone for the second. (Hanrahan, 2013) In his work, Bressand argues that these two approaches are often contrasting, and represent two different political and economic philosophies. (Bressand, 2012)

Another main driver behind strong renewables agenda in the Europe has been the integration of the "polluter pays" principle, first introduced in 1972 by the OECD Council on Guiding Principles concerning International Economic Aspects of Environmental Policies, into all policies, especially energy policies. (Fouguet & Johansson, 2008)

As already briefly described above, during the time between acceptance of Directives 2001/77/EC and 2009/28/EC there were strong disagreements on whether a pan-European support scheme, based on tradable certificates, should be initiated.

Directive 2009/28/EC in its final form set the target of 20% renewables in Community's final consumption by 2020, but did not establish a common mechanism for support to reach the target (originally proposed by the commission in their renewable energy roadmap in 2007). The overall target was divided by Member States into binding national targets.

Member States have published and notified the Commission a forecast document about the estimated progress in reaching national binding targets. The commission has summarised the national forecasts in its own published summary. According to the summary, the overall target should be achieved with at least a 0.3 percentage point surplus by the effect of ten countries exceeding their targets. Only five Member States have estimated a deficit in their progress. (European Commission, 2010)

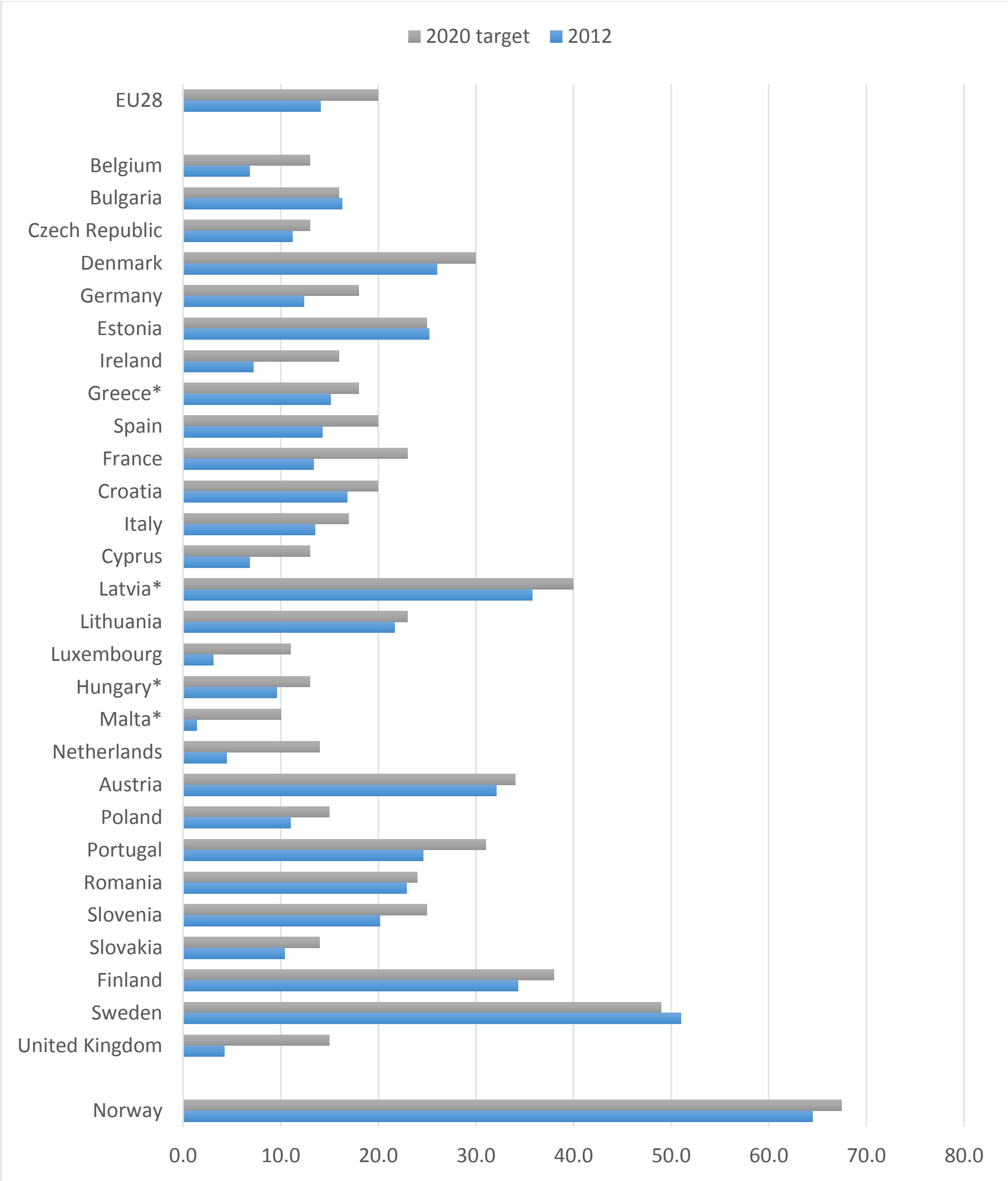

Figure 5.1: Share of renewable energy in % gross final energy consumption in 2012 compared to national 2020 targets (Eurostat, 2014)

**Eurostat estimates based on the national data transmission under Regulation (EC) No 1099/2008 on energy statistics.*

5.2. Toward 20-20-20

Currently, Member States have implemented a variety of national support schemes in order to achieve their binding targets. When looking at the variety of deployed support mechanisms, there seems to be a state of confusion in the energy market. (Raadal, et al., 2012) Cooperation between Member States is minimal, due to the significant differences and strict bindings to national actors in the support mechanisms. The joint tradable green certificate scheme in Norway and Sweden is a unique exception to this tendency towards independent schemes.

Europe's three climate and energy targets for 2020[18] are interrelated and mutually support each other. The targets are monitored using three headline indicators: greenhouse gas (GHG) emissions; share of renewable energy in gross final energy consumption; and primary energy consumption. In addition, contextual indicators are used to present the driving forces behind the headline indicators. (Eurostat, 2013)

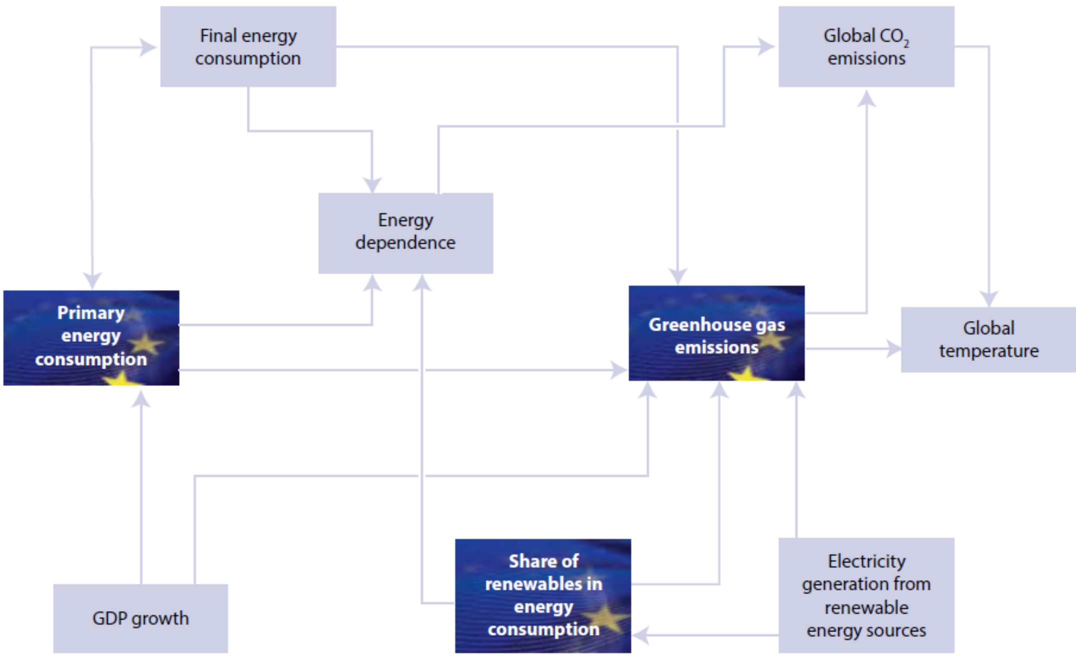

Figure 5.2: 2020 targets' headline and contextual indicators (Eurostat, 2013)

EU's GHG emissions are already approaching the 2020 target. All sectors, except transport, have lowered their emissions compared to the 1990 base year. (Eurostat, 2013)

[18] Reducing GHG emissions by 20 % compared to 1990 levels, increasing the share of renewables in final energy consumption to 20 % and moving towards a 20 % increase in energy efficiency. (Eurostat, 2013)

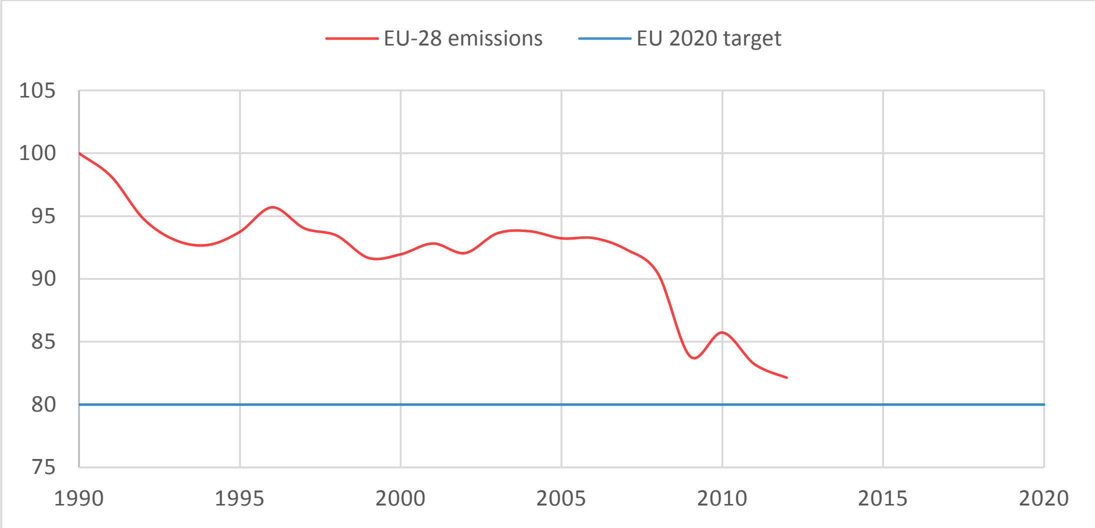

Figure 5.3: EU-28 Greenhouse gas emissions (index 1990=100). Data from Eurostat (t2020_30)

The second energy and climate headline target of the Europe 2020 strategy is to increase the share of renewable energy in gross final energy consumption to 20% by 2020. The progress has been positive from 2004 to 2011, with an increase of 60% in renewable energy in consumption resulting in 13% of overall consumption from renewables in 2011. (Eurostat, 2013)

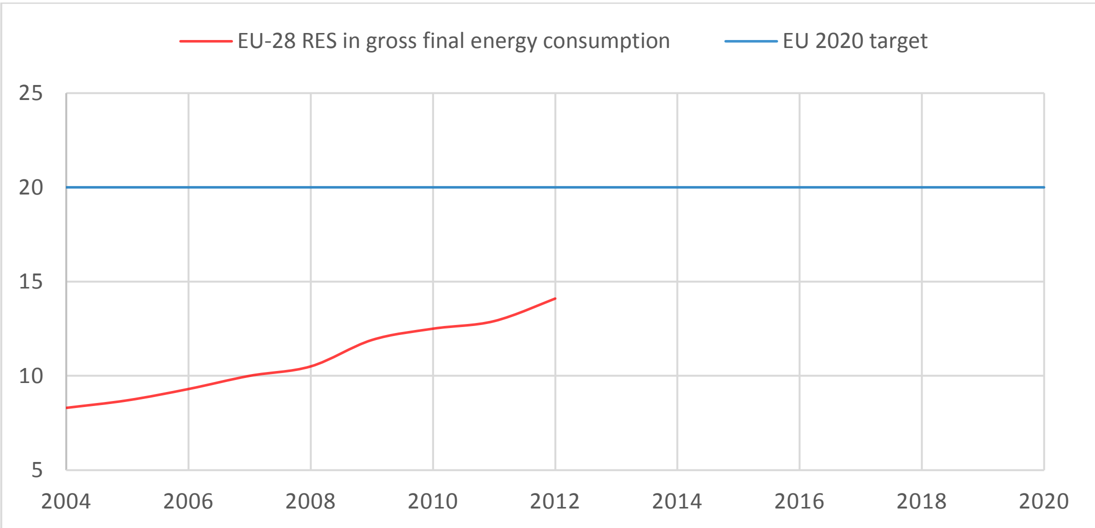

Figure 5.4: EU-28 renewable energy in gross final energy consumption. Data from Eurostat (t2020_31)

The third Community level target, to increase energy efficiency by 20%, has also undergone progress, as the base year level was reached in 2005. After 2006, the overall consumption has declined, but the trend has not been continuous. (Eurostat, 2013)

5.3. Reference scenario

The European Commission's "Energy, transport and GHG emissions trends to 2050 – Reference Scenario 2013" describes the consequences of current policies in a longer timeframe. It sets out from year 2015 as its starting point and predicts the development of different socioeconomic sectors of the EU in five-year cycles up until 2050. In the reference scenario, development is estimated using the framework adopted until spring 2012. It acts as a benchmark scenario predicting future developments as they would play out if the framework would remain as it is. (European Commission, 2013d)

For the energy sector, 2020 targets are generally expected to be achieved. For renewable energy, its share in gross final consumption is estimated to be 20.9% in 2020. It is presumed that after 2020, no targets are set and direct support schemes are generally phased out. However, power generation from RES is expected to further increase after 2020. With status quo framework, renewables are estimated to account for 24% and 29% in 2030 and 2050 respectively. This rise is due to three main factors: continuing advancement in renewable technologies; the effect of the emissions trading scheme; grid improvements and related priority dispatch and improved market-based balancing. Below figures show the reference scenario development for different RES-E sources as well as the overall RES-E share in electricity generation. (European Commission, 2013d)

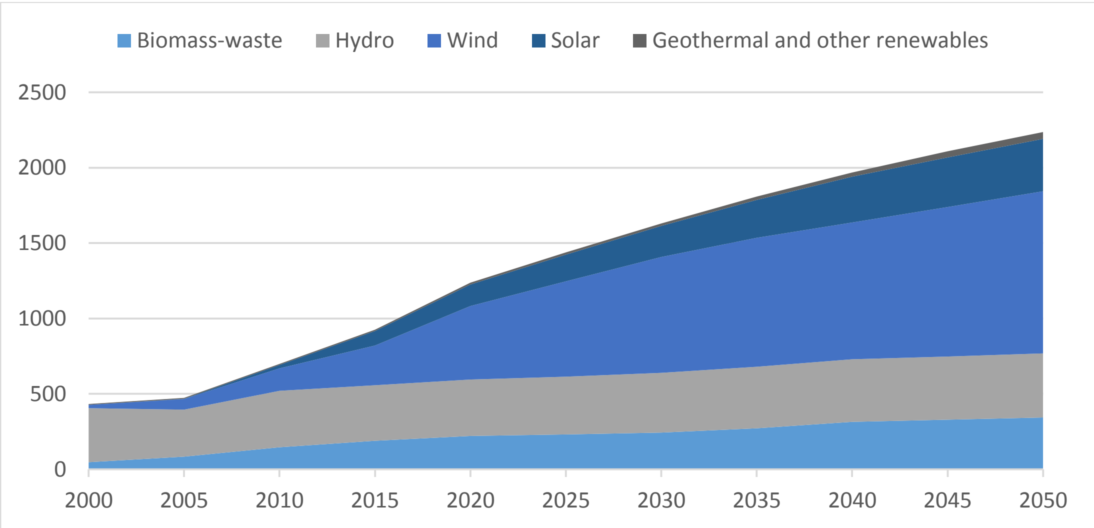

Figure 5.5: European Commission's Reference Scenario 2013 renewable electricity generation 2000-2050 (TWh)

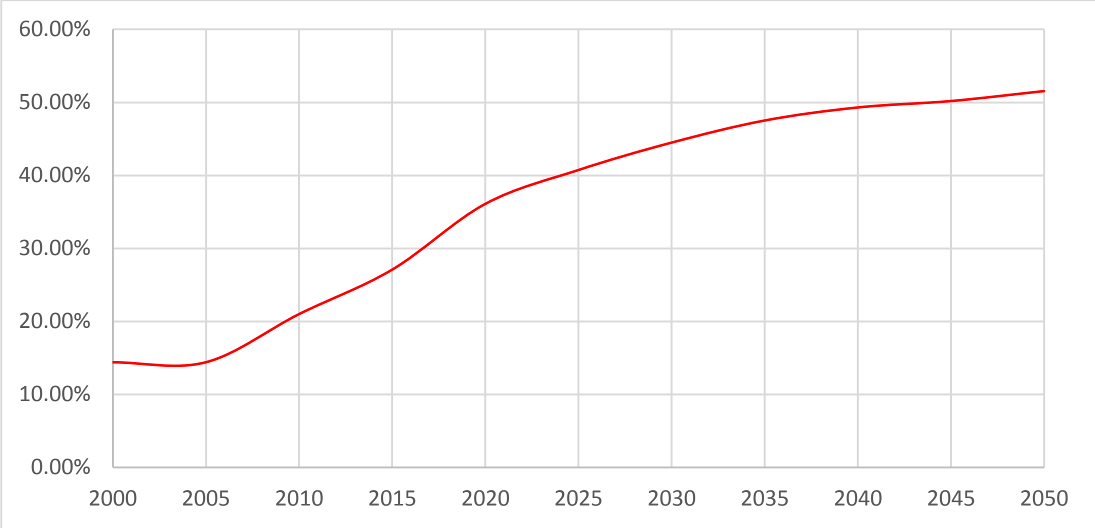

Figure 5.6: European Commission's Reference Scenario 2013 renewable electricity share in total electricity generation 2000-2050 (%)

EU's Roadmap for moving to a low carbon economy in 2050 has set milestones in minimum GHG emissions reduction of 40% in 2030 and 80% in 2050 (both relative to 1990). The presented reference scenario leaves a considerable gap between the milestone targets and predicted development by estimating only 32% and 44% reductions for 2030 and 2050 respectively. The figure below illustrates the reference scenario's evolution of GHG emissions including emissions from both ETS and non-ETS sectors. (European Commission, 2013d)

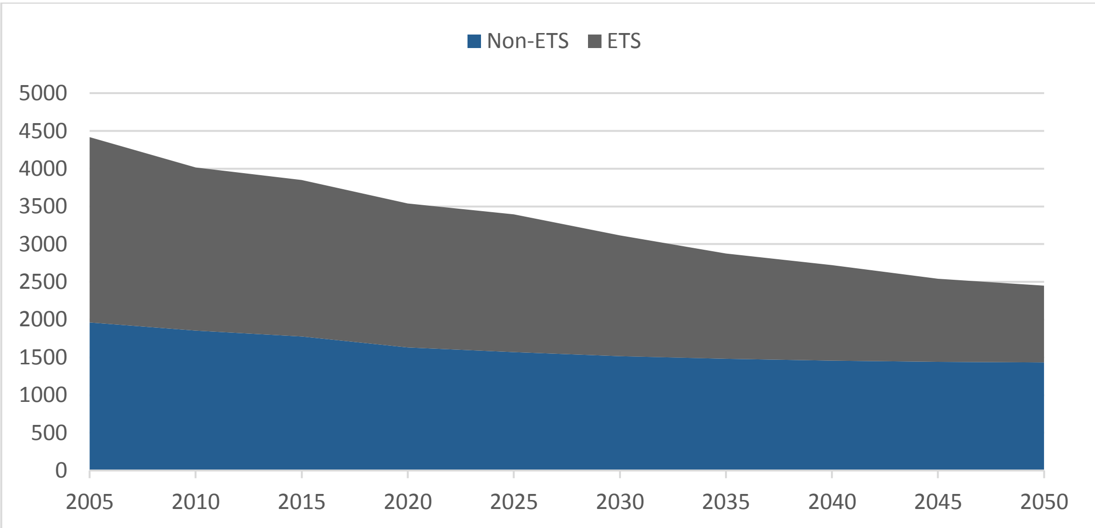

Figure 5.7: European Commission's Reference Scenario 2013 greenhouse gas emissions 2005-2050 (Mt CO_2)

The reference scenario is meant to be used as a tool for measuring the effects of different political, and other, developments. As shown by the model, current commitments are not enough to reach the high targets of 2050. The reference scenario makes it clear that further development in promotion of low-carbon development is needed.

5.4. Future views

The underlying guidelines for future support scenarios are put into place within the European Commission's Energy Roadmap 2050. This communication recommends a long term target of reducing greenhouse gas emissions to 80-95% below base year 1990 levels by 2050. The roadmap is created to be the basis for developing a long-term European framework together with all stakeholders. (European Commission, 2011b)

On 22nd Jan 2014, the European Commission published a communication outlining its vision of the framework for climate and energy policy in the period from 2020 to 2030. In accordance with the 2050 roadmap, it emphasises the need to continue to drive progress towards a low-carbon economy that would provide all consumers with affordable energy, ensure growth and increase security of supply. Deviating from the current triple-target framework, the Commission's proposal revolves around a single Community level target: to reduce GHG emissions by at least 40% compared to the 1990 base year. This goal is expected to be the most cost-effective way towards a low-carbon economy, which in itself should drive an increased share of renewable energy and energy savings. (European Commission, 2014a)

The main target would be allocated to both the Emissions Trading Scheme (ETS) and non-ETS sectors, of which the non-ETS part would be divided among Member States. The communication delivers a concern about the risks of further fragmentation in the internal energy market due to the underperformance of the ETS system to drive investments in low-carbon technologies. This in turn increases the likelihood of new national policies that undermine the level playing field the ETS was meant to create. It should be noted that the Commission is seeking the Council's and the Parliament's approval for the 40% GHG emissions reduction target by early 2015 as part of the international negotiations on a new global climate agreement to be concluded at the Paris climate and energy convention held at the end of 2015. (European Commission, 2014a)

For the renewables, the Commission recommends an EU-level binding target of 27% of final consumption by 2030. Member States are expected to form national plans for competitive, secure and sustainable energy. This assignment is to be completed under Commission's guidance, applying a common approach to ensure stronger investor certainty and greater transparency, as well as enhancing EU-level coherence. For power generation in general, the communication expects the cost structure to change from expenditure on fuels towards innovative equipment with high added value. (European Commission, 2014d)

In the Commission's communication, it is repeatedly underlined that the increased flexibility for Member States must be combined with an increased emphasis on the need to complete the internal market in energy. Different schemes need to be rationalised to better meet the needs of an internal market, become more cost-effective and provide greater legal certainty for investors. (European Commission, 2014a) In another study by Hanrahan, the internal energy market is also seen as a key to cost-competitive way of decarbonisation that delivers "clear added value in pulling Member States' energy policies together…" (Hanrahan, 2013)

The completion of the internal energy market remains an immediate priority for the Commission, providing needed cost-signals and the necessary environment for the most cost-effective solution for the energy policy objectives. For this, state aid guidelines for energy and environment also have to evolve into more market-oriented solutions, better reflecting the evolving cost structures of energy technologies. As such, subsidies for already mature technologies should be phased out entirely by the year 2030. However, for new and immature technologies with significant potential, subsidy schemes would still exist. A high level of competition itself is seen as an essential factor in making progress toward all 2030 objectives. (European Commission, 2014a) Commission has also emphasised that the market is currently not working as effectively as it should in its interaction with current climate and energy targets. (European Commission, 2012a) This is especially evident in the case of differing national support schemes that fail to address the diminishing need of the maturing technologies for support, thus threatening to make the transition to low-carbon economy excessively expensive. (Hanrahan, 2013)

As concluded in IIEA's report, the road to a European regime for the 2020-2030 period will not be easy, as the Community will need to address a complex matrix of targets. It will have to answer questions about achieving decarbonisation at minimal cost, enhancing energy security, achieving the best use of resources, delivering growth and jobs, asserting technology leadership while staying competitive and respecting Member States' internal energy control. (Hanrahan, 2013) Going further, the 2050 targets set by the energy roadmap will require massive investments, like electricity storage capacity and DC super-grid systems in addition to RES support, which makes it even more important to keep support costs at manageable levels. (Capros, et al., 2012)

6. Environmental economics

6.1. The underlying theory

This chapter seeks to briefly explain why renewable electricity generation currently needs support schemes to develop in the environmental economics' point of view. In order to be brief, the theory is covered for the parts most relevant, leaving out broader underlying economic background. The chapter mainly builds upon work done by Hanley et al. in the second edition of *"Environmental Economics – In theory and practice"* published in 2007 by Palgrave MacMillan.

"People have less incentive to protect the environment today when the social costs fall on others in the future" (Hanley, et al., 2007)

The above sentence partly describes the problem in purely market-based solutions from an environmental point of view. The problem is that markets often fail to allocate all, especially long term, societal costs of producing energy to the producer. For example, it is often the case that generating electricity from fossil fuel is more competitive in terms of generation costs because all related costs are not borne by the producer. These costs are referred to as negative externalities. (Hanley, et al., 2007) By subsidising technologies with positive externalities, or by penalising technologies with negative externalities, governments are trying to optimise the welfare of the entire society. (Klimscheffskij, 2011)

Environmental economics introduce a concept of the optimal pollution level (OPL) – a theoretical aim for a society where the combined marginal profit (MP) and marginal damage cost (MDC) of all producers are equal in price, thus defining the optimal production level where the social welfare is maximised. The aggregated MP for all power producers is referred to as the marginal net private benefit (MNPB) and the aggregated MDC as the marginal external cost (MEC). (Klimscheffskij, 2011)

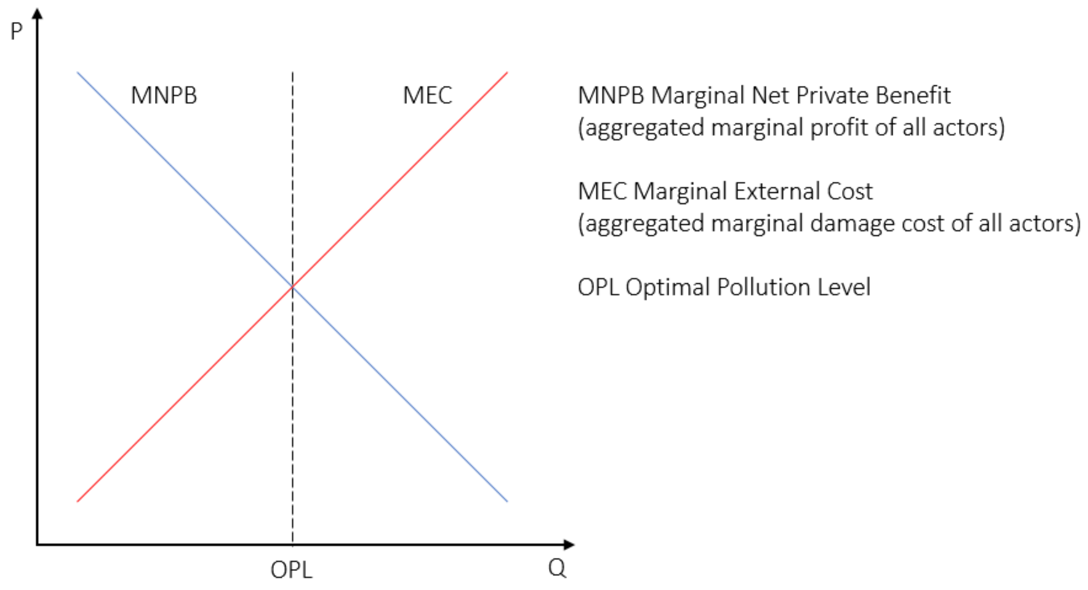

Figure 6.1: Optimal pollution level. Based on (Klimscheffskij, 2011)

In order to find the optimum balance, the OPL, all relating costs from externalities have to be included in individual cost curves. However, this is often problematic because of the not-so-evident long term costs of power generation, such as global warming, and fair burden sharing. When all marginal social costs (MSCs) are not included in producers' marginal production costs, it results in higher production volumes than what would be optimal according to the OPL. It is clear that this is not sustainable in the long run. (Hanley, et al., 2007)

Negative externalities can be added to the cost curve by either penalising polluters by requiring extra financial burden to be carried by the polluters or by allocating extra revenue to non-polluters in terms of support schemes. These two approaches have the same outcome of promoting the "greener" option. As mentioned before, another way of grouping these schemes is to divide them into price- and volume-based mechanisms. In price-based systems, causing no pollution is seen as a positive externality, while in volume-based systems polluting is regarded as a negative externality. (Hanley, et al., 2007)

Price-based systems are often characterised by heavier regulatory burden. For example, feed-in tariffs are a price-based support scheme where positive externalities of renewable generation are awarded with fixed revenue. A penalising example of a price-based system would be the carbon tax, which imposes a fixed extra cost to generation deemed as polluting. Volume-based systems usually rely on market forces to optimise the support and penalty levels. Tradable green certificates and the emissions trading scheme (ETS), often referred to as cap-and-trade system, are textbook examples of volume based mechanisms of allocating externalities.

In theoretical assessments, the volume-based system is often preferred due to its market orientation and cost-effectiveness. (Klimscheffskij, 2011) Practical studies, however, often accuse volume-based systems for creating investor insecurity (thus higher risk premiums) and promoting mature technologies with lower marginal costs over still emerging immature solutions. (Held, et al., 2014) However, this can also be seen as promoting competition among different renewable technologies, further enhancing the cost-effectiveness. (Mananteau, et al., 2003) Price-based is often seen as the more stable scheme with lower required risk premiums. However, price-based systems are not market-compatible (a possible exception being feed-in premiums that partly rely on market forces) and are very limited in terms of flexibility. (Held, et al., 2014)

6.2. Support scheme design – common elements

This chapter briefly discusses the general features applicable for all support schemes. It strongly builds on a report published by ECOFYS in 2014, "Design features of support schemes for renewable electricity", and the European Commission's staff working document "European Commission guidance for the design of renewables support schemes" for guiding renewables support schemes (SWD(2013) 439).

The European Commission, in its staff working document, discusses the needed reform in renewables support schemes. While emphasising the need for long term commitments on the legislative side to provide investors predictability and reliability, the Commission also states that the support mechanisms need to become flexible enough to account for changes in the development of costs and technologies. The support schemes need more market exposure in order to ensure that energy production is driven by competitive energy markets. (European Commission, 2013a)

In its report, supplementing the Commission's guidelines, ECOFYS has described different design options common for all support schemes. These are: administrative determination of price and volume elements, policy cost control and adaptation of support levels, burden Sharing of RES-support, differentiation of support level design, predictability, stability and flexibility, and integration into electricity markets. (Held, et al., 2014) The next chapters are designed to give an overview of these options.

6.2.1. Administrative determination of price and volume elements

The most common tool for calculating/estimating the needed support level (the amount of support) is the calculation of levelised cost of energy (LCOE). The methodology first determines the relevant cost parameters. Secondly, it estimates the project revenue in order to enable the administrative determination of either the needed support level in cases of price-based support, or the multiplier for a technology-specific quota in the case of a volume-based mechanism. Other contrasting means of determining the level of price-based support are auctions and tenders that organise access to financial support and set the level through a bidding process. (Held, et al., 2014)

Some Member States have also chosen to set support levels according to positive externalities of renewables such as avoided emissions or increase in security of supply. However, these methods are seen to rely too much on estimations and to not reflect the costs of producing energy very well. (Held, et al., 2014)

As presented by Klessmann et al., the LCOE presents the present value of the total cost of building and operating a production unit over its financial life. This also sets the amount of revenue demanded from the project during its economic lifetime. (Klessmann, et al., 2013)

6.2.2. Policy cost control and adaptation of support levels

The increasing amount of renewable energy deployment to the support market is making the cost control and support adjusting increasingly important. The general approach to cost reduction is setting a cap either in terms of volume or costs. Additionally, control policies may differ in terms of the time horizon for which the volume or cost limit is defined, technology level (being either technology-neutral or –specific), and budget monitoring and control as well as dynamic caps. (Held, et al., 2014)

Volume-based support schemes inherently include a limiting cap in the form of the set target. Volume-based solutions, however, include a risk of extremely high or low certificate[19] prices in cases where no penalty payments or floor-prices are introduced. Penalties, while motivating actors under quota to fulfil their share, also create a price-cap for tradable certificates. All European TGC systems have included penalty payments. (Held, et al., 2014)

[19] Tradable Green Certificates (TGC) are the tool for fulfilling quotas, required shares of renewable electricity in the overall consumption mix, in a volume-based support scheme. Certificates are electronic documents containing the electricity generation attributes and they can be traded separately from the physical electricity.

For price-based systems, no inherited cap exists, and a supervised revision and adaptation of the initially set support levels is crucial to policy cost control. Support scheme revision for price-based systems can be seen as balancing between minimising investor risk and adjusting support level to be more cost-effective.

One way of limiting support policy cost in price-based system is to set a fixed regression rate, where the support diminishes at a predetermined pace. Experiences from countries that adopted this approach show that fixed regression does not fit well with new technologies, like solar PV, that have a very dynamic cost development. Production cost changes in general are also hard to predict for time periods as long as required for support schemes.

Another approach is to introduce periodic reviews assessing the rate of support. This method, however, requires precise data on production volumes and costs that can be difficult, and sometimes expensive, to collect. Longer periods between reviews address this issue, but on the other hand make the scheme more vulnerable to the same weaknesses that are typical to fixed regression rates.

Support caps can also be set according to deployed capacity. This option, however, requires very precise modelling in order to produce the desired results. There have been many cases where this type of regression/cap has had quite the reverse consequences compared to the underlying goal. (Held, et al., 2014)

Finally, there is an option to set a monetary cap on the overall budget for support. This type of restriction is expected to produce environmentally (and other) desired results in coherence with the rest of the national budget and seems reasonable. However, being a high-level restriction, it does not actually address the problem of allocating the support most efficiently. It rather sets a limit or a goal to the national financial effect of the overall support scheme. This alternative also has a negative effect on investor confidence, since it introduces a risk of being excluded from the capped support scheme.

Mir-Artigues and Del Rio have found in their work that in case of price-based support schemes the capping of RES-E generation eligible for support is the most efficient way of controlling policy costs over time, although it is noted that it also has its weaknesses. (Mir-Artigues & del Rio, 2014)

6.2.3. Burden sharing of RES support

When considering fair burden sharing, there are many contradicting aspects to be taken into account. Focus is often drawn to opposite effects of renewable support and competitiveness of energy-intensive industry. While considering the exemption of some industrial actors from support burden, the effect on the remaining bearers should also be considered. (Held, et al., 2014)

Another important aspect in burden sharing is the fact that the Community has decided to implement the "polluter pays" principle in all policy domains, especially in the domain of energy. (Fouguet & Johansson, 2008)

6.2.4. Differentiation of support level design

Support levels can be common throughout the scheme or differ significantly by e.g. technology. Technology-specific support volumes are introduced due to the differing marginal costs of energy production. A uniform support level would lead to windfall profits for more mature technologies with lower marginal costs, since the average support level would be higher than needed by these more competitive technologies.

The need for technology-specificity often follows the cost-potential curve. In cases when the cost-potential curve is flat, technological specification is not needed. This might be the case when technology diversity is low (only few viable options) or when the production costs for different technologies are similar.

ECOFYS has, however, estimated that the cost-potential curve in Europe is too steep for technology neutrality and thus in most cases technology-specific remuneration levels need to be introduced. In practice, this means different support for different technologies. Taking a step further, it is sometimes plausible to introduce intra-technology diversification in order to promote certain generation attributes, or to make the system even more cost-efficient. Many countries have implemented different support levels in a specific technology sector using criteria as location (e.g. wind), used fuel (e.g. biomass) or scale of the plant (e.g. solar or biomass).

One argument for the technology-neutrality would be the affected drive toward the most efficient technology resulting, in theory, the highest overall capacity development. Fitting the market-oriented approach, technology-neutral levels are more common in volume-based support schemes than in price-based ones. However, due to a variety of reasons, technology-specific allocation has also occurred in many volume-based mechanisms. (Held, et al., 2014)

6.2.5. Predictability, stability and flexibility

There is a common contradiction in all support schemes. From an investor's point of view the support should be predictable and stable. This often translates into low required risk premiums. However, the policy maker often needs the support mechanism to be flexible and adapt to changing circumstances, which helps the support mechanism to be cost-effective.

In order to provide a stable environment for investments, long-term legal framework is needed. On the most general level this could mean clear renewable targets. The policy will have to be built on a solid foundation ensuring its existence over a longer time frame. In addition to being permanent, the policy should ensure the investor that no unexpected changes will happen during the financial period of a relevant investment. Thus, measures of flexibility, if applied, need to be predictable and based on known, transparent elements. (Held, et al., 2014) As presented by Klessmann et al., the assessment of a potential RES project includes detailed risk estimations in four categories, one of which being policy and regulatory risk. It includes the assessment of risk of sudden and/or retroactive changes in support policy. (Klessmann, et al., 2013)

Rathmann et al. have also underlined the importance of political stability. In their work, risks concerning the physical plant, like risks from construction, operation and technology, are seen as bearable by the RE project itself, whereas the regulatory risks, like risks from abrupt policy changes and retroactive changes, should be covered by the public. (Rathmann, et al., 2011)

In context of revenue stability, as later discussed, the risk for the investor is minimised by stabilising the project income. This means that at the expense of market responsiveness, risk can be reduced by providing fixed price. (Held, et al., 2014)

6.2.6. Integration into electricity markets

Ambitious targets in RES generation inevitably raise issues of integrating renewable technologies to existing markets. Requirements for addressing these issues can, and should, be set on both sides – renewable generation and existing market.

System responsibilities for RES-E generation consist of different measures allowing the integration of larger quantities of renewables. These are (as presented by Held et al.):

- Demand-oriented generation features in support schemes
- Balancing responsibility for renewable power plants

- Remote control dispatch
- Provision of system services

Demand-orientation is one of the key features in enabling larger integration of renewable generation into existing markets. As described before, because of minimal short-term marginal costs, renewables are dispatched first to meet consumer side demand. Thus, when renewable share rises in the overall mix it should also be generated according to market demand.

Larger amounts of intermittency due to RES-E production also results in higher demand for balancing power – controllable generation that “fills the gaps” between day-ahead market contracts and hourly production capacity. (Held, et al., 2014)

The two latter measures supplement the former requirement for balancing. Remote control dispatch allows centralised dispatch decisions to prevent extreme negative prices and unnecessary grid congestion. Provision of system services would include renewable producers in maintaining essential grid properties like set frequency and voltage. It should be noted that these proposed measures will become easier to apply through the aforementioned aggregator actor.

7. National support schemes

Current national support schemes in Europe aim at achieving the 20-20-20 targets. While assigning the Member States binding targets, the Union did not impose common premises for national support mechanisms. Thus, the national support schemes of today are very heterogeneous and do not cooperate among each other (except the Swedish-Norwegian quota system).

Table 7.1: Combinations of primary and secondary instruments for RES-E deployment support in the EU. (Mir-Artigues & del Rio, 2014)

AT = the instrument is applied to all RE technologies; W = wind on-shore; WOF = wind off-shore; B = biomass; Bg = biogas; SH = small hydro; PV = solar photovoltaic

Country	Primary instrument	Secondary instruments
Austria	FIT (AT except SH and PV<5 kW) Investment subsidies (only PV<5 kW, Climate and Energy Fund)	
Belgium	Quotas with TGCs (AT).	Tax deductions (AT) Investment subsidies (Brussels, W, H, B) Investment subsidies (Flanders, PV).
Bulgaria	FIT (AT) Tender (PV>100 kWp)	Soft loans (AT, small projects only)
Cyprus	FIT (AT, large projects) FIT (AT, small projects)	Investment subsidies
Czech Rep.	FIT or premium (AT, excluding large W farms >20 MW, on-ground PV and roof-top PV>30 kW)	Investment subsidies Low interest loans (W)
Denmark	FIP (AT excluding WOF) Tenders (WOF)	Investment subsidy for small RES-E systems (AT) Loan guarantees (W) Net metering (PV) Tax relief (PV).
Estonia	FIP (AT)	Investment subsidy (W) Exemption from electricity production tax
Finland	FIP (W, Bg, B)	Investment subsidies (AT, including PV).
France	Tenders (WOF, PV>100 kW on buildings and ground-mounted) FIT for the rest (including PV in buildings <100 kW)	
Germany	FIT/sliding FIP (AT)	Low interest loans (AT)
Greece	FIT (AT)	Investment subsidies or tax exemption (AT)
Hungary	FIT (AT)	Investment subsidy (AT)
Ireland	FIT	Tax relief
Italy	Quotas with TGCs (existing plants) FIT (existing plants <1 MW) FIP (>1 MW and <1 MW which do not choose the FIT, except solar plants)	Reduced VAT rate Net metering

	New plants: FIT provided through tenders for large projects. New plants: FIT for medium-size and small projects	
Latvia	FIT (AT)*	Investment subsidy Tax exemptions from the electricity tax
Lithuania	FIT (<10 kWh, AT, except geothermal)** Net metering (PV<20 kW)	Investment subsidies Soft loans
Luxembourg	FIT (AT)	Investment subsidies (AT)
Malta	FIT (PV)	Investment subsidies (PV+W for households <3.7 kW) Soft loans Tax credit on investment (PV)
The Netherlands	FIP (PV>15 kW)	Soft loans (AT, excluding WOF) Investment subsidy (PV) Net metering (PV<15 kW)
Poland	Quotas with TGCs (AT)	Soft loans (AT) Investment subsidies (AT) Exemption from electricity consumption tax (AT)
Portugal	FITs (AT)***	Tax relief
Romania	TGCs (AT)	Investment subsidies (AT)
Slovakia	FIP (AT)	Investment subsidies (AT) Exemption from electricity consumption tax (AT)
Slovenia	FIT/FIP (AT)	Investment subsidies (AT) Low interest loans
Spain	FIT/FIP (AT, existing plants before January 2012).	Tax relief
Sweden	Quota with TGCs (AT)	Tax exemptions (B, W, peat and RES-E<100 kW) Investment subsidies (PV, large-scale WOF)
U.K.	Quota with TGC schemes FITs (<5 MW)	Tax exemption (from the Climate Change Levy).

* *The FIT is granted on the basis of a tender*

** *Installed capacity > 10 kW is awarded through tenders. The government quarterly sets the maximum FIT for the subsequent tender procedures.*

*** *Tenders for solar PV and mini-hydro are used to allocate the right to connect to the grid. Tenders for wind and biomass are used to set the support level.*

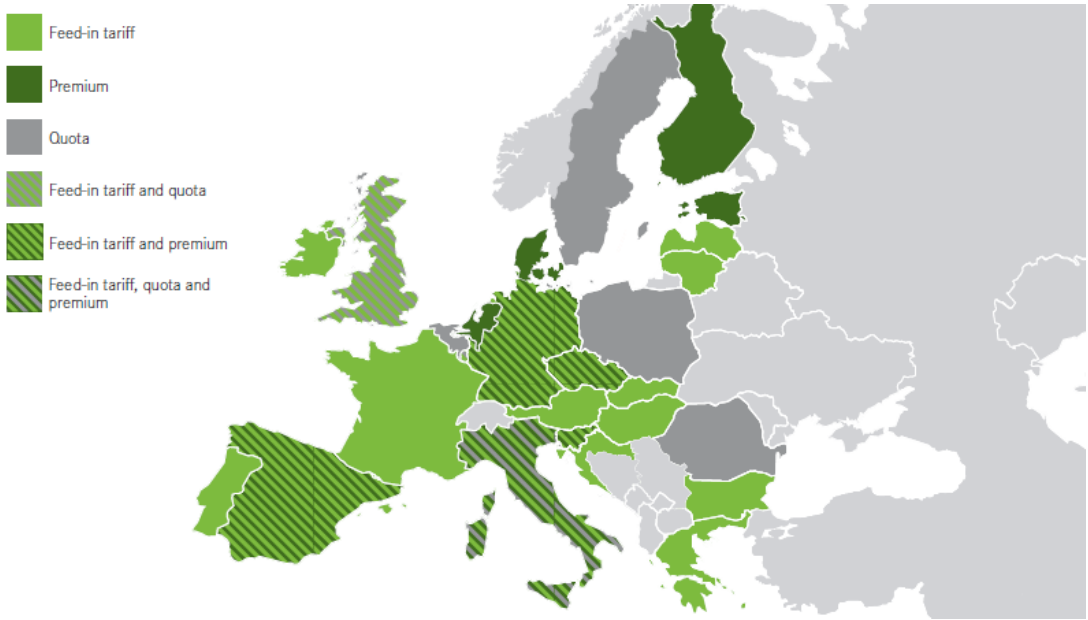

Figure 7.1: Primary national support schemes in Europe (Fortum, 2014)

As an overview, national support schemes can be divided using a few criteria. First, a Member State should decide whether the support is based on the amount of generated electricity or installed capacity. In Europe, generation-based policies have dominated over the capacity-based ones.

Second, more dividing criteria, is the decision between volume-based and price-based scheme. In the latter, price based system, national government sets the price for renewable generation and the capacity develops according to the cost-potential curve. (Held, et al., 2014) As briefly touched upon before, there are guidelines for governments on how to set the price level, but capacity development is still practically impossible to predict on an even relatively exact level. (Menanteau, et al., 2003)

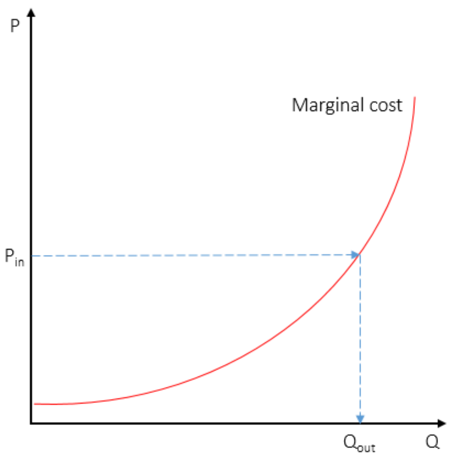

Figure 7.2: Price and volume determination in price-based system. Based on (Mananteau, et al., 2003)

Volume-based systems take a different approach. The quantity of renewable generation is decided on a national level. The amount is then divided among operators (consumer, retailer, distributor or producer) in individual quotas. Operators then have to fulfil their quota by producing the amount of renewable energy or by buying the necessary amount of certificates from another operator. (Menanteau, et al., 2003)

The below figure presents a simplified example of a volume-based system where two producers, A and B, are assigned equal production quotas q. Actors have distinct marginal cost curves MC_A and MC_B. The certificate market allows producer A, who has significantly higher marginal production costs, to limit its production rate to Q_A and cover the rest of the quota with certificates bought at equilibrium price p. The bought certificates come from producer B, who is able to increase its production volume to Q_B because of the lower marginal costs and the demand for certificates. Thus, the overall objective is reached with reduced costs. (Menanteau, et al., 2003) (del Rio, 2005)

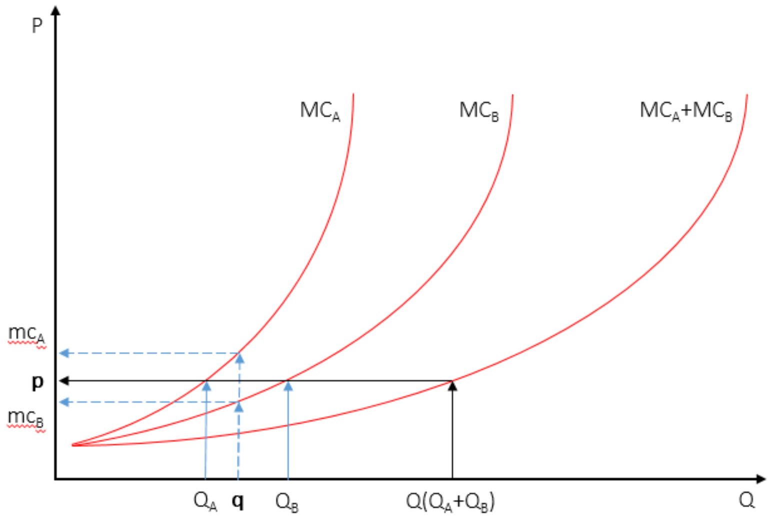

Figure 7.3: Price and volume determination in volume-based system. Based on (Mananteau, et al., 2003)

The third criteria for support scheme comparison is the coverage of the support. A support scheme can provide overall remuneration or it can cover only a part of the overall costs. In the latter, option revenue is partly dependant on electricity retail price. (Held, et al., 2014)

Table 7.2: Main characteristics of support schemes (FIT, FIP and Quota)

	Feed-in tariff	Feed-in premium	Quota obligations with TGC
Generation-based	X	X	X
Capacity-based			
Price-driven	X	X	
Volume-driven			X
Total support coverage	X		
Partial support coverage		X	X

In the following sections, different implications of national support schemes are presented. The focus is on comparing price-based feed-in tariffs and premiums to volume-based quota/TGC systems. Auction schemes are not separately presented, since, rather than being support mechanisms, auctions and tenders are regarded as systematic approaches in determining support levels and allocation. Investment support and tax exemptions are also excluded for being structurally different[20] from compared schemes.

7.1. Feed-in tariffs

Feed-in tariff (FIT) is a price-based support mechanism where, for a set of eligible producers, the national authority establishes a fixed price for each kWh fed into the grid. Price levels can be common for all producers, but more often price levels differ from technology to another because of different marginal costs. (Held, et al., 2014) RES support is thus dependant only on the amount of generation, which in turn is not dependant on market signals. (Fouguet & Johansson, 2008) Electric utilities, on the contrary, are in some implementations obligated to buy electricity from these renewable producers at this higher level. (Schaffer & Bernauer, 2014)

Effect to power generation can be simplified by comparing production levels with and without FIT. As shown in the figure below, with a market-based price the production level would be lower than with a higher FIT.

[20] Support is given to a project on a different than generation basis.

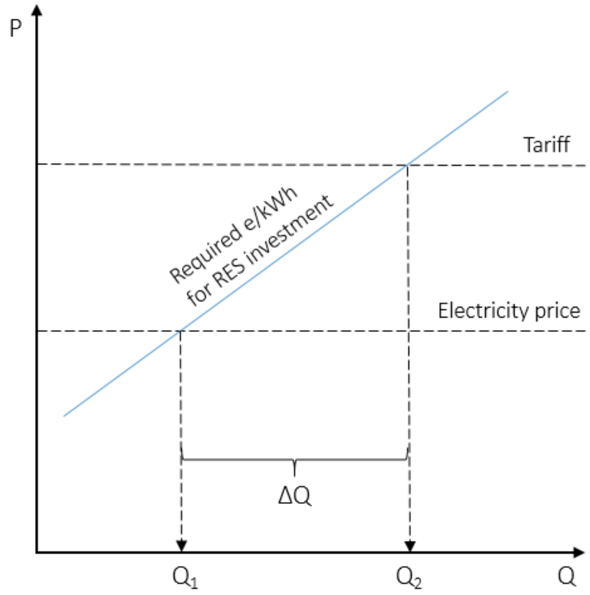

Figure 7.4: Production volume elevation due to set feed-in tariff. Based on (Klimscheffskij, 2011)

It is clear that FIT schemes have been extremely effective in raising the amount of deployed renewable generation. Feed-in tariffs provide the most certain investment environment compared to other schemes. Fixed income flows, given usually for 10 to 12 years, make the project close to risk-free for investors. (Held, et al., 2014) (Schaffer & Bernauer, 2014) (Klimscheffskij, 2011) (Couture & Gagnon, 2010) (Menanteau, et al., 2003) According to Kitzing, using mean-variance approach to compare feed-in tariff (FIT) to its more recent successor feed-in premium (FIP), FITs generally require lower support levels than FIPs while providing the same investment-attractiveness. This is a direct result of minimised risk premiums. (Kitznig, 2014)

Feed-in tariffs, when implemented as technology-specific, promote dynamic efficiency of the system – the long-term cost evaluation of target achieving and capability to drive down costs for emerging new technologies. This underlines the need to specify different support levels to different technologies. (Held, et al., 2014) However, in practice, such needed flexibility has been hard to implement because of the need to maintain the level of support promised to past investors of mature technologies. This often creates unforeseen windfall profits for some market actors. (Schaffer & Bernauer, 2014) As mentioned before, retroactive changes would significantly rise the typically low risk premiums.

Relatively up-to-date assessment of FITs is presented in work by Jenner et al.. The article compares the effects of FIT to onshore wind power and solar photovoltaics (PV). While underlining the importance of model precision in such studies, Jenner et al. conclude that FIT support has only a marginal effect in investments focusing on already mature technologies like onshore wind. The studied strong initiative to invest in onshore wind occurs even during country-years[21] without FIT support. The greatest effect with FIT is achieved with immature technologies, like solar PV, that are not competitive without support. (Jenner, et al., 2013) This is confirmed by Mir-Artigues and del Rio, who state that FITs provide more up-front certainty to public authorities about the total accumulated costs over time, and are particularly suitable for immature and higher risk technologies. (Mir-Artigues & del Rio, 2014)

FIT schemes have been criticised for low cost-effectiveness and their separation from electricity markets. Held et al. argue that low performance in cost-effectiveness is not a trait of FIT itself, but rather depends on the technologies used (Held, et al., 2014). This, however, is not entirely true when considering the before mentioned failure (of the scheme) to introduce flexibility that would reduce the windfall profits. Overall cost-effectiveness is somewhat related to market-orientation in the sense that support should be granted only to production that is generated due to consumer demand. One characteristic of a FIT system is that it does not take into account the signals from the electricity market.

FIT systems have also faced serious critique through claims that the steady price of FIT is provided on the cost of social welfare and thus the social benefit from renewable production is lost. (Tamas, et al., 2010)

The political atmosphere for feed in tariffs is becoming increasingly negative, largely due to high related costs and market separation. Thus, in many instances, it has been communicated that feed-in tariffs should be converted to feed-in premiums.

7.2. Feed-in premiums

Feed-in premium (FIP) systems are more evolved versions of FITs that introduce partial market exposure for producers. (European Commission, 2013a) There are different implications of FIPs, but the general idea is that a premium is paid to a producer for each kWh of electricity generated. Thus, the income level is a combination of electricity price and adequate premium.

The main advantage of a FIP, compared to FIT, is the market orientation. As part of the income is from selling the electricity, the producer/supplier has to market their energy (contrary to previous FIT where produced electricity was automatically bought). However,

[21] Development during a specific year in a specific country

this partial exposure to market mechanisms increases the investment risks. (Held, et al., 2014) As viewed by the European Commission, FIP can still provide a more predictable revenue stream for investments in new, not fully market-ready, technologies compared to a TGC system. (European Commission, 2013a)

There are three main ways of setting the FIP level. The paid premium can be static (fixed amount paid on top of electricity price), fluctuating (size of the remuneration depends on the electricity price) or static with floor and cap limits (fixed premium, but restricted between minimum and maximum overall income). (Held, et al., 2014)

A fixed premium offers producers a predetermined premium for each unit of sold electricity. Thus, market actors need to include electricity price variations in their risk calculations, resulting in heightened risk premiums. This is amplified by government needs to introduce assessment and flexibility measures to the system, which might decrease the support in order to address the changes in RES long-term marginal costs. From an administrative point of view, fixed premiums allow good policy cost estimations, which, however, can be very cost-inefficient if overall electricity price is elevated. (Held, et al., 2014)

A floating premium provides producers a premium that is dependent on the overall electricity price. For example remuneration could be increased in a situation where the electricity price is low and vice versa. This decreases the risk from fluctuating electricity prices. (Held, et al., 2014) A floating premium's effectiveness in terms of market exposure varies according to how often the premium is adjusted. (European Commission, 2013a) The adjustment interval also decides if the support resembles more a fixed premium or a feed-in tariff system – long intervals result in fixed premium -like support and short intervals result in FIT-type remuneration. (Held, et al., 2014)

A premium with cap and floor prices is a premium with (usually administratively) set maximum and minimum limits. Concerning investment risk, the cap and floor model is a compromise between a fixed and floating premium. (Held, et al., 2014)

The European Commission has also noted that FIP should be designed in a way that prevents support when market prices are negative or exceed the level of perceived need for remuneration. (European Commission, 2013a) However, this is not the case in many national schemes (e.g. Germany, Austria and Switzerland).

A functioning FIP system will need to limit costs and drive innovation as well as provide a safe investment environment to provide sufficient development. Cost limitations can be achieved through competitive allocation of support (auctions) and automatic adjustments in cost and support calculations. Investor certainty can be improved by making these processes transparent and predictable. (European Commission, 2013a)

7.3. Quota obligation

In a quota obligation scheme, renewable electricity producer is granted green tradable certificates (TGCs) for each MWh of generated RES-E. TGCs are used to fulfil government assigned quotas (as percentage of total consumption/output) for different market actors e.g. consumers or suppliers. In quota schemes, electricity and certificate (attributes) markets are separated. (Klimscheffskij, 2011) It should be noted that the certificate market, like all other support markets, is currently created by an artificial demand. (Haas, et al., 2011)

The greatest merit of a quota system is its market compatibility. The producers of renewable energy need to sell their electricity on the market independently from the support, which lays them open to market mechanisms, although the merit order effect usually guarantees that renewable electricity is sold first. Similarly, the certificates are sold on a competitive market where price is determined automatically. With this also comes the most common vulnerability of quota obligations – the heightened investment risk. As repeated in various studies, price fluctuations, which in case of TGC occur cumulatively in two markets, increase the risk of premiums demanded by investors. This leads to a decrease in actual generation compared to a theoretical level of generation. (Klimscheffskij, 2011) The risk can be lowered by implementing long term transparent and planned quotas and making market data available for all stakeholders. Additionally, a quota scheme can set a minimum certificate price (floor price). (European Commission, 2013a) Raadal et al. have also found that investor risk can be lowered by increasing market size, thus making the market more liquid and certificate prices more robust. (Raadal, et al., 2012)

Market operators, who bare the set quota, have different marginal cost curves for producing renewable energy themselves. Thus, trading TGCs allows one operator to fulfil the quota according to a marginal cost curve of the most suitable producer for renewable electricity. Thus, overall targets are achieved cost-efficiently, although market actors and enablers have only incomplete information about the market. (Mananteau, et al., 2003)

Mananteau et al. continue that price- and volume-based mechanism are not equal in such cases of incomplete information[22]. A price-based system would not be capable of providing

[22] Here depollution costs are used as an example by Mananteau et al.

an indication of actual production volumes resulting from the allocated support. A volume-based system, however, enables direct control over the amount of generated renewable electricity. A price-based system would have to apply successive adjustments in order to achieve the desired target. (Mananteau, et al., 2003) These, often retroactive, measures can have strong undesired consequences on investor security.

Applying the same logic provided by Mananteau, it could be argued that volume-based systems fail to set a cap on policy cost for market operators. Such speculations are justified, since there is a possibility for certificate prices to become excessively expensive, e.g. in case of Australia. This problem can, however, be addressed by penalty prices that set a cap on certificate price. Penalties are also recommended to ensure quota/target fulfilment. (European Commission, 2013a)

Quota obligation schemes can be technology-neutral or technology-specific. The technology-neutral option promotes maximum competition and drives down technology costs, thus achieving the short-term goal at minimal costs. (European Commission, 2013a) This option is often criticised for failing to promote small producers with limited capital and new technologies that require larger amounts of support to be competitive. Mature technologies are also often accused for receiving windfall profits. Consequently, technology-neutral quota obligation is best suitable in cases where the cost-potential curve is rather flat. (Held, et al., 2014)

In cases of a steep cost-potential curve, obligations can also be created with technology binding. In some cases more than one certificate can be issued per MWh for more expensive technologies[23]. Alternatively parallel quotas can be set for different technologies/technology groups. These options make small and new actors more competitive in the market and cut unnecessary windfall profits. (European Commission, 2013a) However, it can be extremely difficult to predict the needed separate quotas or multiplication factors in cases where the national target should be divided into smaller parts. (Held, et al., 2014)

A quota system also complies better with the polluter pays principle. In TGC systems, the cost of polluting can be added to the costs of either consumers or alternatively polluting power

[23] This approach, as suggested in reviewed literature, is however not recommended by this study. As discussed in ending chapters of this thesis, if renewable electricity support and disclosure would be implemented through a uniform certificate system, it would be extremely hard to justify this alternative.

plants. It contributes directly to switching from fossil-based production to renewable production.

The following figure shows how introducing a TGC system results in an increase in RES production and a decrease in other (usually fossil) production.

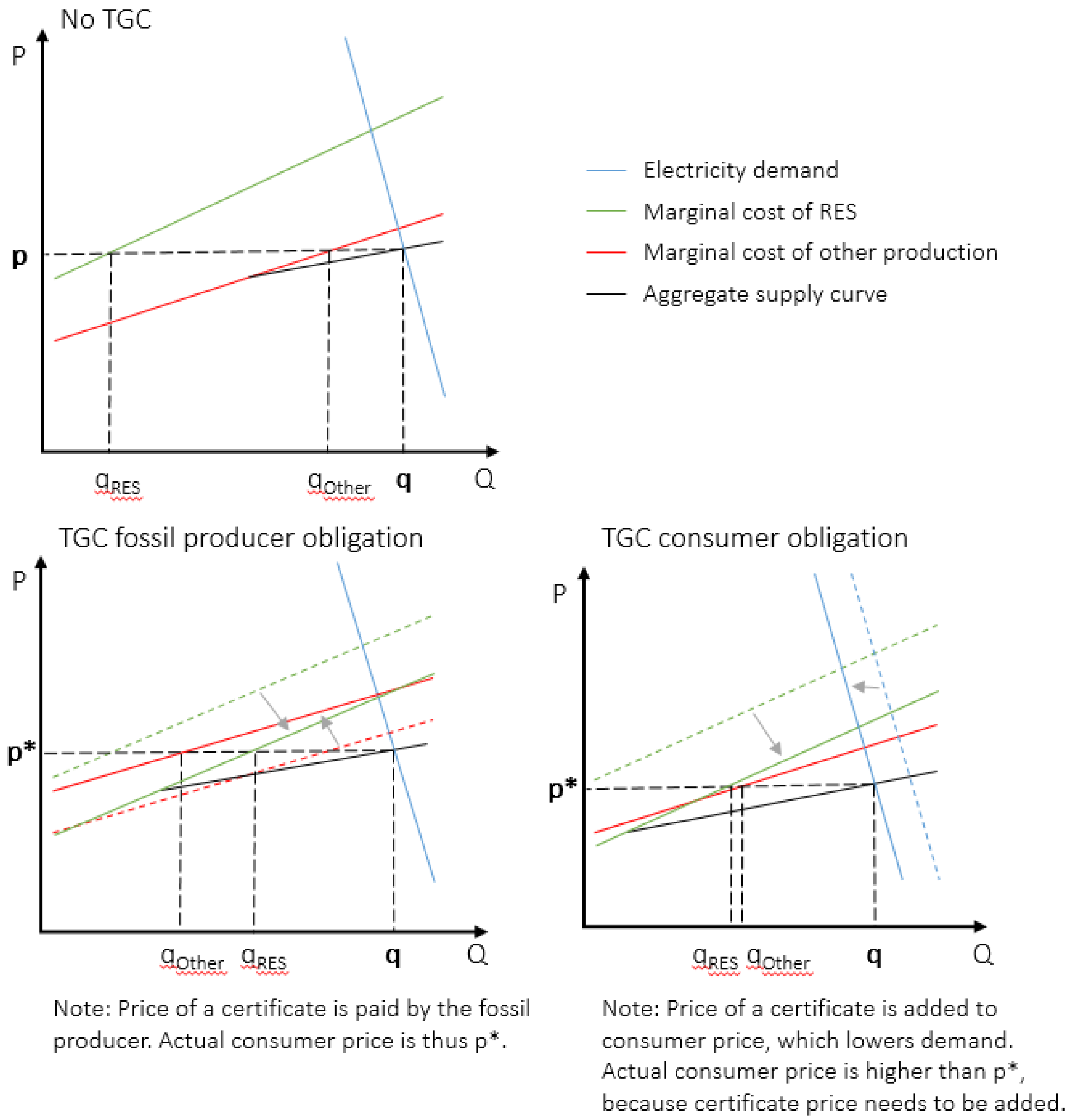

Figure 7.5: The effect of TGC on renewable and other electricity production. Based on (Klimscheffskij, 2011)

7.3.1. Tradable Green Certificate markets

TGC markets should be optimal in creating revenue for renewable generators that is equal to the difference between long-term marginal costs (LTMC) and electricity price. This is also the price of a TGC required to make RES-E investment profitable. Thus, new and existing producers are expected to bid on the equilibrium price – much like electricity producers in electricity markets. All existing renewable generation, with only very low short-term marginal cost (STMC), also automatically participates in the market. This can be seen in the figure below, where the supply curve is at zero for the extent of already existing capacity. As new capacity has to be introduced, the cost of supply rises according to the LTMC. The price is restricted by set minimum and maximum prices. (Klimscheffskij, 2011)

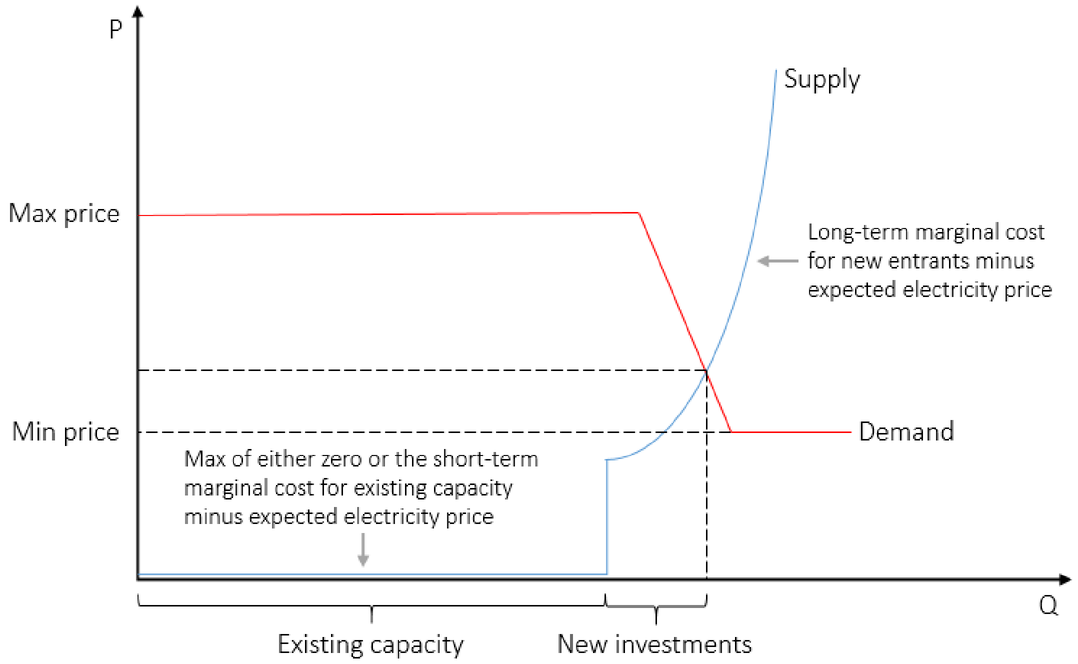

Figure 7.6: Supply and demand curves in competitive TGC markets. Based on (Lemming, 2003)

It is clear that production volume fluctuations, typical to intermittent renewables, will increase the investor risk. Imperfect market information about supply and demand also raises the risk. It is thus essential that the regulator makes the market as transparent as possible. Conversely, wind fluctuations actually tend to reduce the short-term financial risk due to the negative correlation between production volume and TGC price (large amounts of wind energy will result in large amounts of TGCs and lower price). (Lemming, 2003)

Another peculiarity of the TGC market is that selling forward contracts will tend to increase the financial risk for generators with a stochastic production volume. (Lemming, 2003) Thus, forward contract sellers can demand extra risk premiums. TGC forward sellers should sell at an expected profit until they reach the point where the mean and variance of revenues matches their risk aversion. (Klimscheffskij, 2011)

Tanaka & Chen have published results about possible strategic behaviours of renewable and non-renewable producers on TGC markets. They conclude that dominant market powers can have a strong influence on electricity and certificate prices, which they can use to their advantage. Thus, market authorities are urged to carefully oversee the market performance and mitigate market the power of dominant actors. (Tanaka & Chen, 2013)

TGC markets, as currently implemented e.g. in Sweden and Norway, do not have an impact on consumers' options to purchase or claim more or less renewable electricity. This is due to the fact that quota levels are government-set and are not influenced by voluntary purchases. (Raadal, et al., 2012)

8. Support volumes

The purpose of this section is to give a short overview of the renewable electricity generation in a set of European countries, and compare it to the level of support allocated to the achieved amount. The following section is not intended to give a detailed overview of renewable energy generation in all EU28 countries, but rather establish a connection between the recent development of renewable generation and the amount of support used. For this purpose, a set of 13 countries[24] was chosen. The countries were chosen by assessing their data-availability[25].

The following figures show the development in absolute renewable electricity generation (in MWh) from 2009 to 2012, and the share of renewables in total electricity generation during the same period. Data from ENTSO-E[26] and Eurostat[27].

---

[24] Austria, Belgium, Czech Republic, France, Germany, Hungary, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain and Sweden

[25] In order to construct a reliable dataset, following volumes for 2009-2012 had to be available: yearly generation of electricity from RES in total, RES generation divided into main energy sources, yearly volume of share of renewable electricity generation eligible for support, breakdown of eligible RES generation into main energy sources.

[26] https://www.entsoe.eu/data/data-portal/production/Pages/default.aspx

[27] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

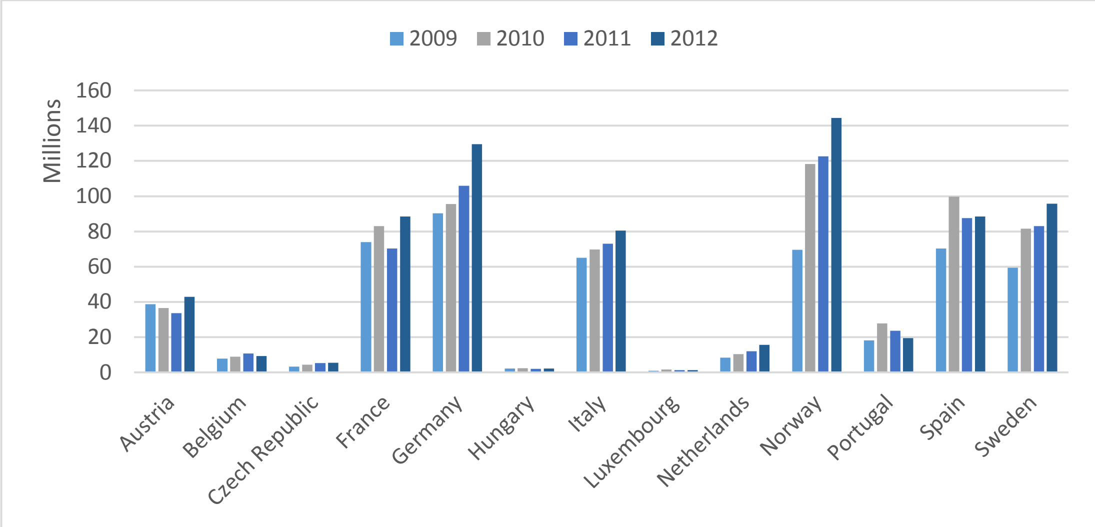

Figure 8.1: Renewable electricity generation 2009-2012 (MWh)

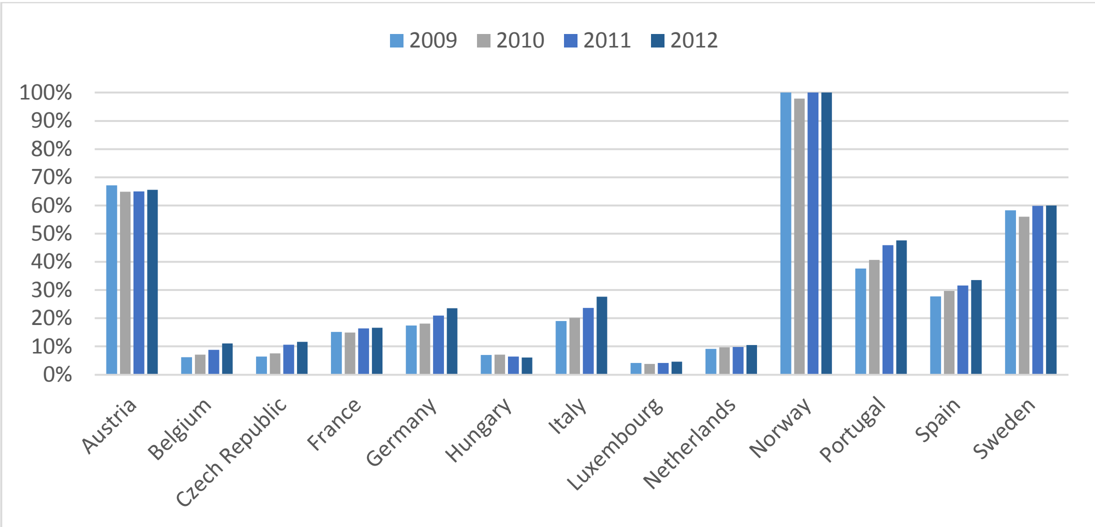

Figure 8.2: Renewable electricity share in overall electricity generation 2009-2012 (%)

Various sources[28] were used to gather data on recent volumes of remunerated renewable electricity generation. The below figure presents the share of renewable generation that was eligible for support in the selected countries. Notice that data was generally not available for 2012 (except for DE and AT), thus a forecast was used. Forecast presented in green.

[28] (CEER, 2013) (CEER, 2011) (50Hertz, Amprion, Tennet, TransnetBW, 2009) (50Hertz, Amprion, Tennet, TransnetBW, 2010) (50Hertz, Amprion, Tennet, TransnetBW, 2011) (50Hertz, Amprion, Tennet, TransnetBW, 2012) (Lange, 2013) (Doerr & Lange, 2012) (Proidi, et al., 2011) (E-Control, 2012) (Boltz & Graf, 2013) (Statnett, 2014) (Svenska kraftnät, 2014)

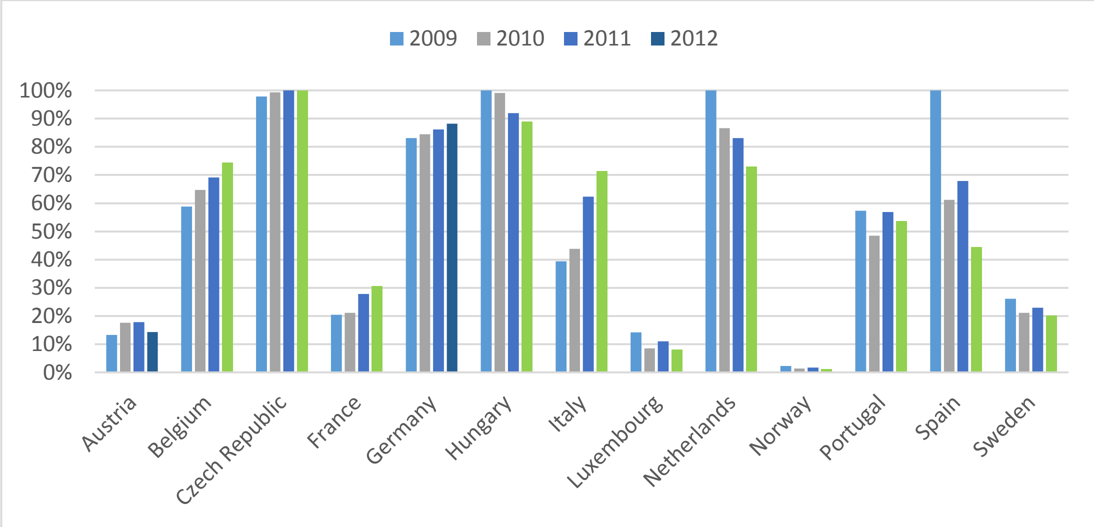

Figure 8.3: Share of renewable electricity generation eligible for support 2009-2012 (%)

The above figure shows that although large parts of renewable production are eligible for support, there are still significant differences between countries. This is mainly due to the large amount of renewable generation that is not eligible for support (e.g. large scale hydro that is fully competitive on its own). If the focus is put on technologies that are currently still, at least partly, developing, the amount of eligible generation rises substantially.

It can be insightful to compare above graphs of RES-E production and support to similar graphs including only wind and solar PV, since most of the renewable growth during the last decade can be attributed to these technologies (European Commission, 2014c). The below graphs show the development of wind and solar generation in the country set and compare them to the generation volumes eligible for support.

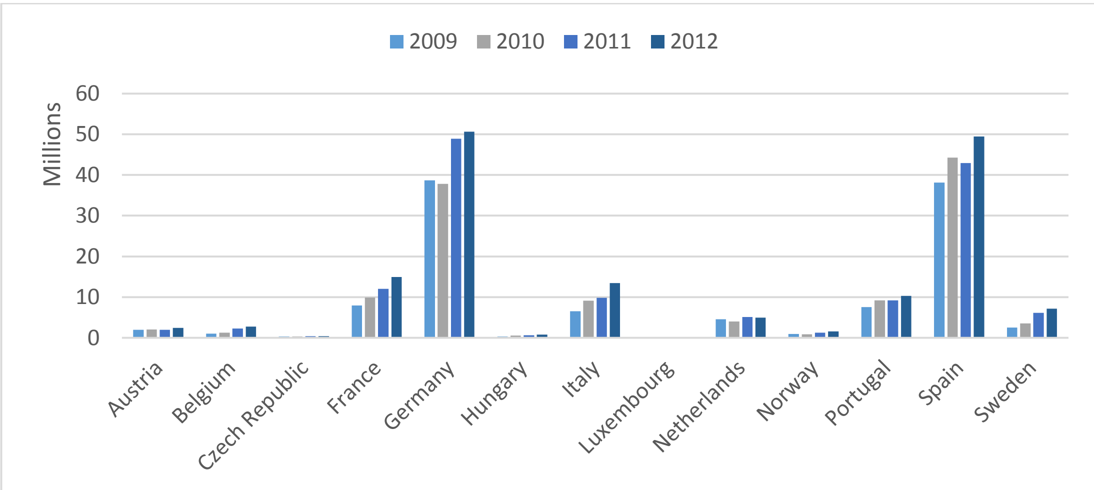

Figure 8.4: Wind power generation 2009-2012 (MWh)

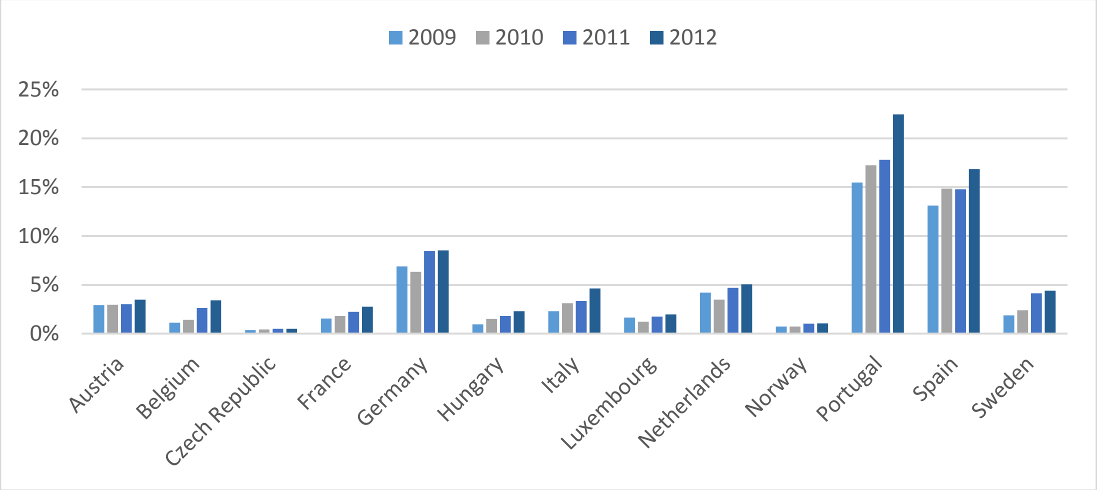

Figure 8.5: Wind power share in overall electricity generation 2009-2012 (%)

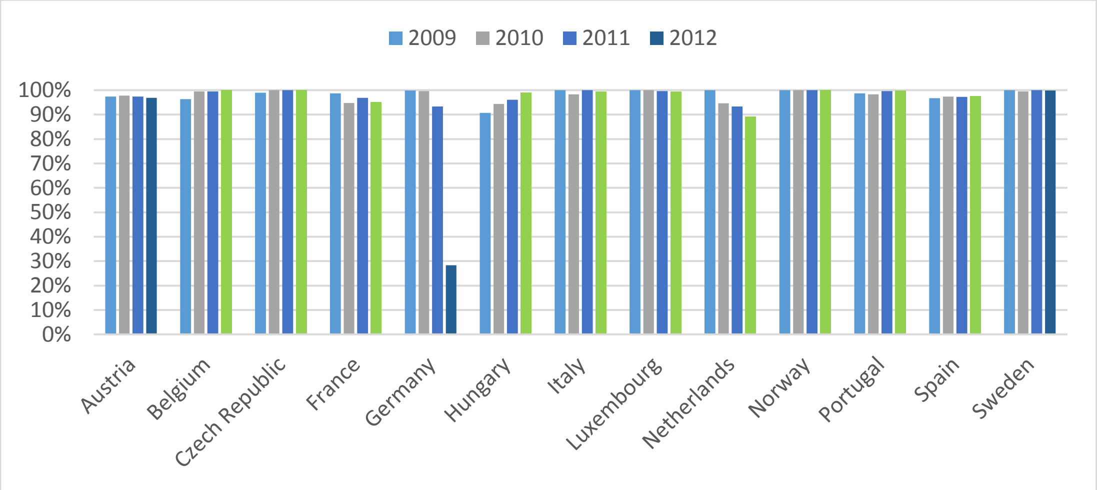

Figure 8.6: Share of wind power generation eligible for support 2009-2012 (%)

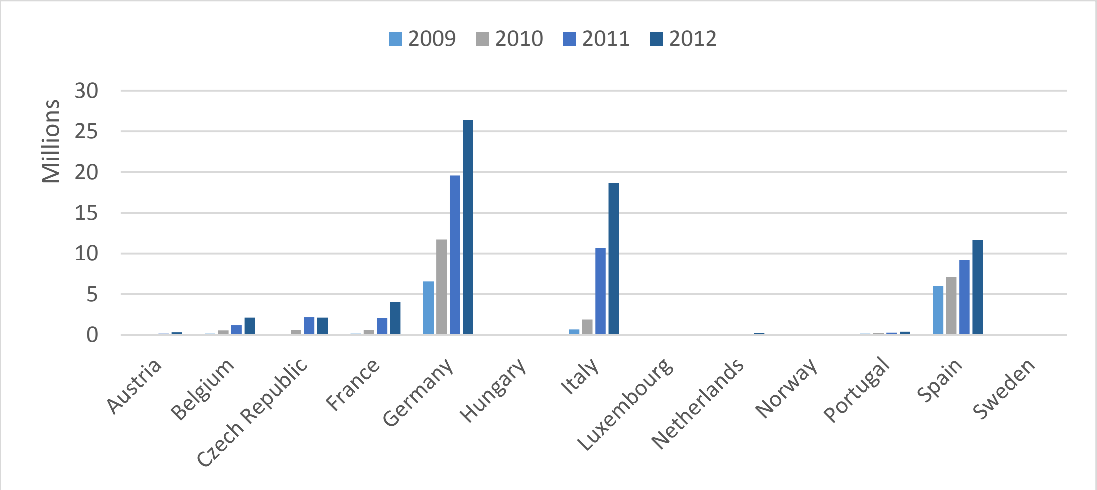

Figure 8.7: Solar power generation 2009-2012 (MWh)

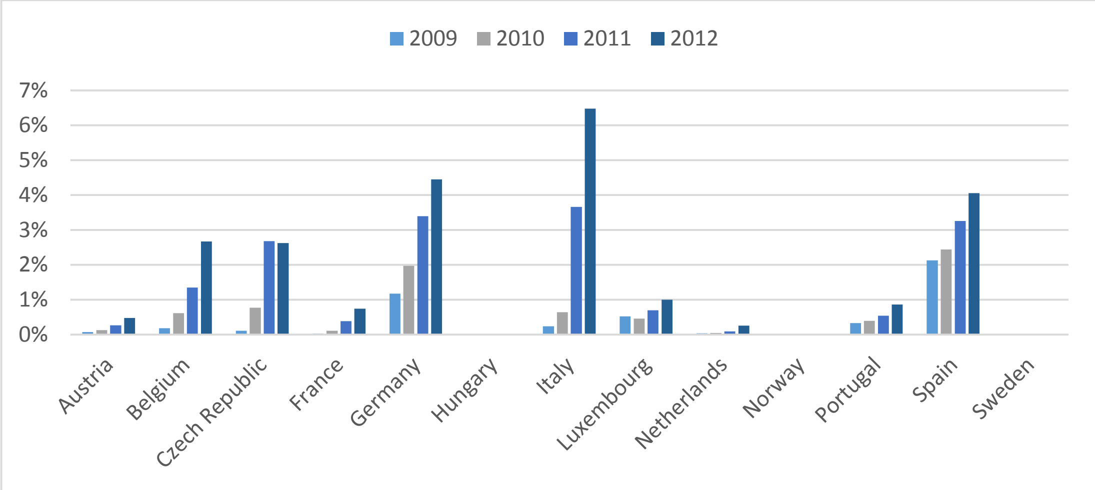

Figure 8.8: Solar power share in overall electricity generation 2009-2012 (%)

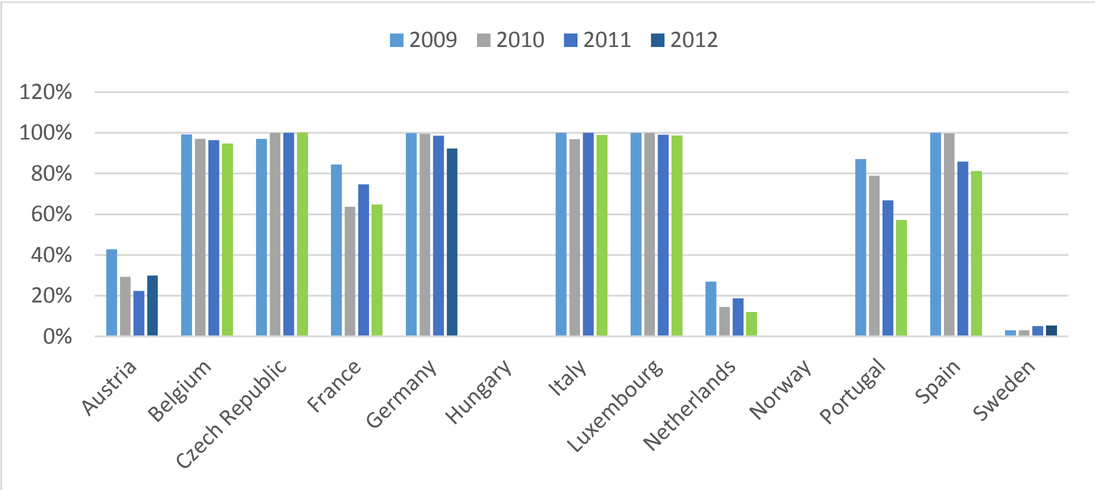

Figure 8.9: Share of solar power generation eligible for support 2009-2012 (%)

The above graphs show that nearly all wind and solar PV electricity production is eligible for support. This is emphasised in the case of wind, where practically all generation is remunerated. Support eligibility has brought considerable development to solar and wind generation. The European Wind Energy Association (EWEA) has compared volumes of new and decommissioned power capacities for different production technologies in 2013 (Figure 8.10: New installed power capacity and decommissioned power capacity in Europe in 2013 (MW)). They show that wind and solar power have by far the most new capacity in Europe, leaving gas and coal third and fourth respectively. It should be noted that gas and coal power capacities were also heavily decommissioned.

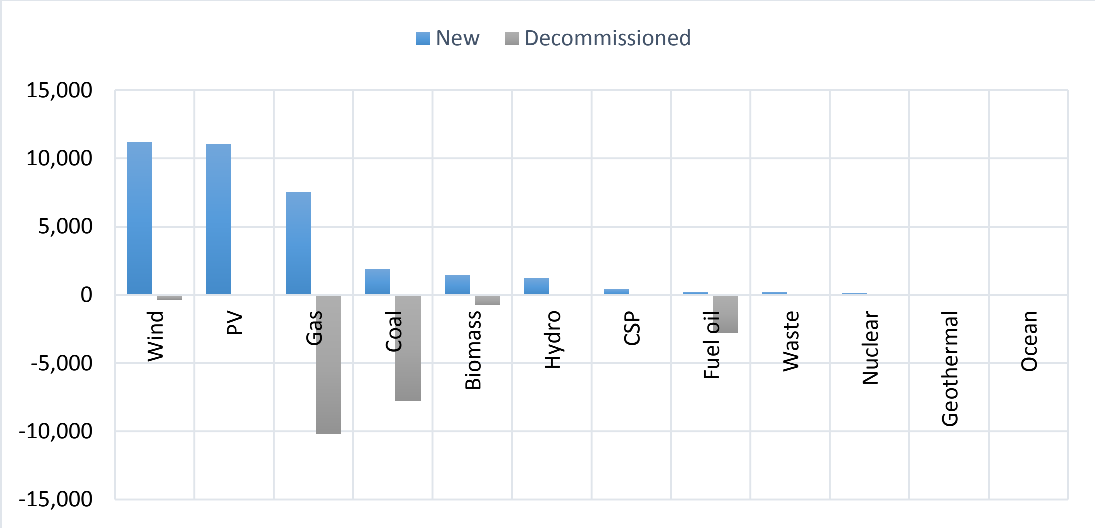

Figure 8.10: New installed power capacity and decommissioned power capacity in Europe in 2013 (MW) (EWEA, 2014)

It might be useful to compare the development to hydro power where support is nearly non-existent and in cases of eligibility is very specifically focused. The below figure presents the development of absolute hydropower generation development in years 2009-2012. It should be noted that only limited comparisons between mature hydropower and developing wind- and solar power can be made, since, being independently competitive (grid parity reached), sources for hydropower have in many cases been exhausted and yearly fluctuations are mainly due to different rainfall amounts.

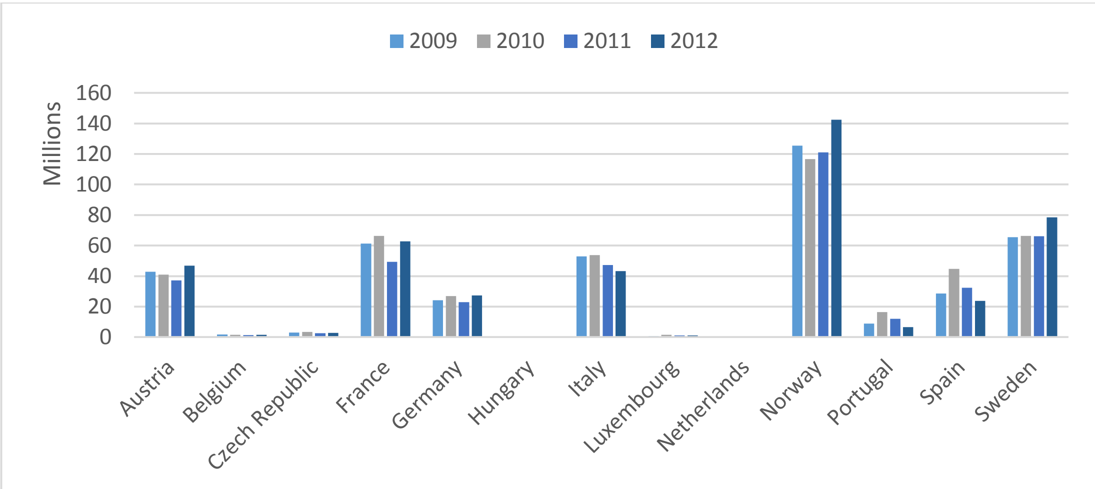

Figure 8.11: Hydro power generation 2009-2012 (MWh)

On the economic side, in order to assess the performance of different support schemes, it is useful to reduce highly different amounts of generation to monetary levels of support required to produce 1 MWh of renewable electricity. Data in below figures was gathered by combining CEER's support scheme status reports with other reliable data[29]. On higher RES-E level the average support levels per MWh and their recent developments (2009 – 2011) are presented below.

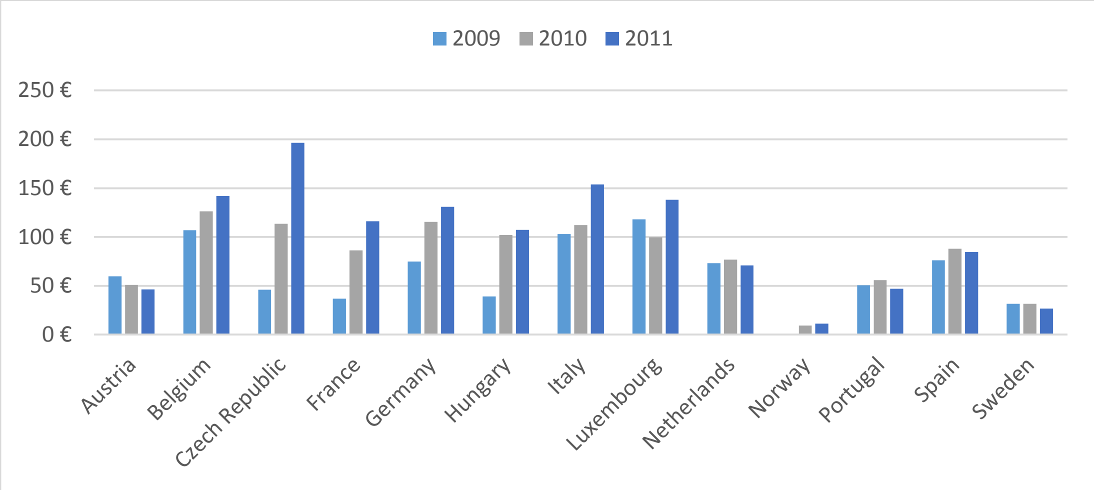

Figure 8.12: Average cost of support (€/MWh) for renewable electricity generation 2009-2011

In order to get more information on the differences between renewable sectors, it is useful to present average support levels per technology for wind- and solar power.

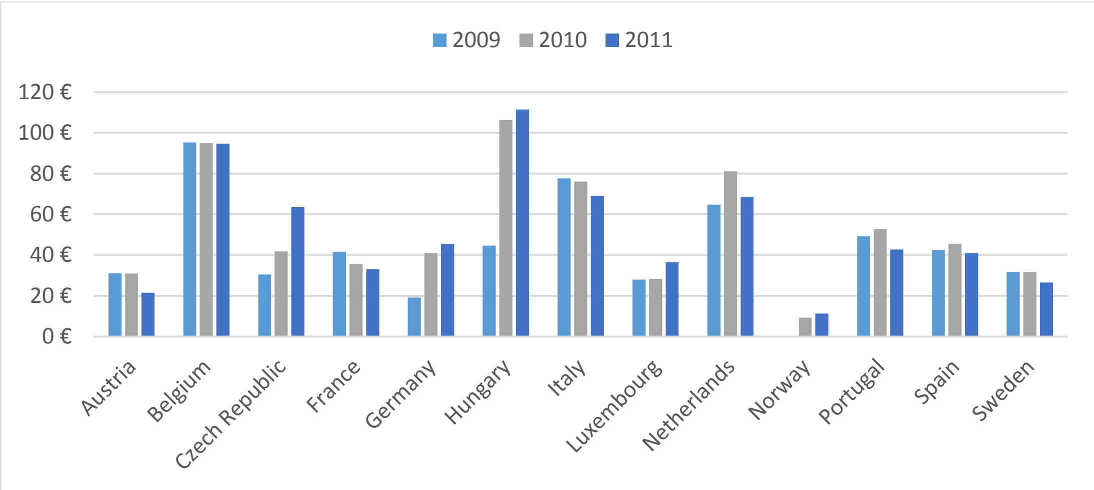

Figure 8.13: Average cost of support (€/MWh) for wind power generation 2009-2011

[29] Data from (CEER, 2011) (CEER, 2013) (50Hertz, Amprion, Tennet, TransnetBW, 2009) (50Hertz, Amprion, Tennet, TransnetBW, 2010) (50Hertz, Amprion, Tennet, TransnetBW, 2011) (50Hertz, Amprion, Tennet, TransnetBW, 2012) (E-Control, 2012) (Boltz & Graf, 2013) (Proidi, et al., 2011) (Doerr & Lange, 2012) (Lange, 2013)

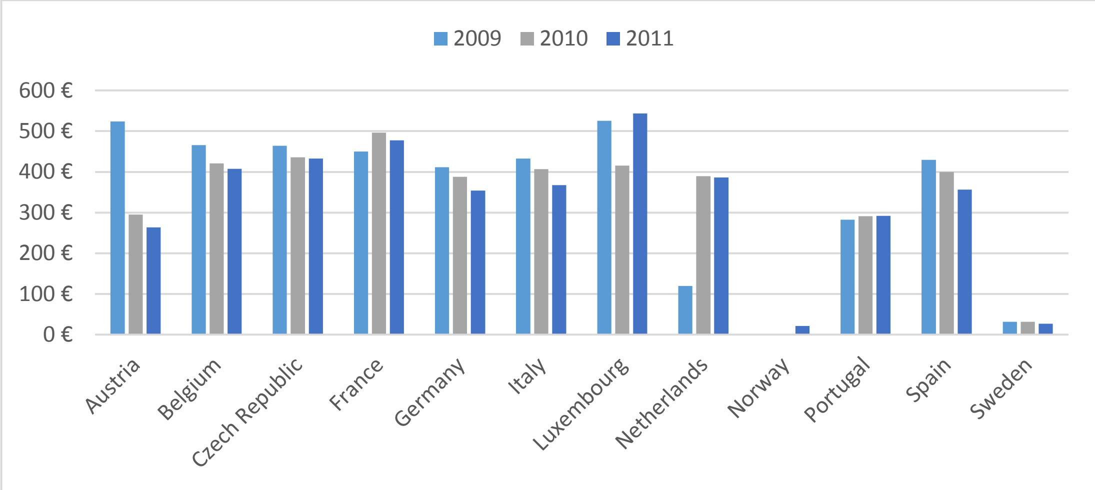

Figure 8.14: Average cost of support (€/MWh) for solar power generation 2009-2011 (excluding Hungary due to lack of data)

Overall cost of support (the overall value of subsidies) has undergone a significant growth during recent years. The Commission has estimated that in 2010 the overall cost of support in EU27 was around EUR 27 bn. 70% of this amount was covered by three leading countries: Germany, Spain, and Italy. They were followed by France and the UK. During 2011-2012, the amount has grown rapidly. For Germany alone, the amount of subsidies rose from EUR 9.5 bn in 2010 to EUR 12.7 bn in 2012. For Spain the figures were EUR 5.4 bn and EUR 8.4 bn respectively. IEA has estimated that for EU27 the total amount of subsidies rose from EUR 27 bn in 2010 to EUR 46 bn in 2012. (European Commission, 2014c)

The costs of support are usually borne by electricity consumers as a surcharge on retail electricity price. Usually, this surcharge is set to be proportional to actual costs, but in some instances (in e.g. Spain and Portugal) the political will is to keep the levels lower, which puts an additional strain on the state budget and therefore a burden on public finance. This can to some extent become counterproductive to reaching the target, as the cost of support is not portrayed in the electricity bill, which increases electricity demand. The average size of this surcharge (average weighted support level) for consumers was 9.3 EUR/MWh[30] in 2010. (European Commission, 2014c)

9. Drivers of change

In the previous chapters we have established a rough model of European electricity markets and the accelerating development toward low-carbon economy. We have built upon steady

[30] Average electricity price in 2010 was 128 EUR/MWh for industrial consumers and 173 EUR/MWh for households.

and approved concepts of market integration, underlying principles of development and general guidelines of energy and environmental policies. The main guiding Community-level documents have been presented and in relevant parts summarised. It has also become clear that implementing these common targets has taken various forms across the Member States, often resulting in compromises, short-term solutions and even contradictions.

The state of European renewable energy framework and its connections to the diversified electricity markets is an extremely complex system – a combination of economical necessities, political agendas and increasingly important requirements of the environment. This thesis cannot hope to go into a detailed structure of this model in order to give a complete recommendation for a fresh build-up or fine-tuning of the existing mechanisms. However, a general insight to a few underlying changes in recent development and their implications in the strategy-bound future until 2050 can be discussed. The following chapters attempt to present some of these changes within the set limits of the thesis.

9.1. Growing share of renewables

In the long run, renewables will move to the centre of the European energy mix. This is one of the major prerequisites for a more sustainable and secure energy system. The renewable production will shift from small-scale technology development to larger-scale mass production and from a subsidised to a competitive form of generation. (European Commission, 2011b)

The Commission, in its Impact Assessment staff working paper accompanying the 2050 Roadmap, has estimated the growth of renewables in 2020-2050, as part of overall estimation of decarbonisation, through five different scenarios. These five scenarios take into account decarbonisation measures like energy efficiency, renewables, nuclear and Carbon Capture and Storage (CCS). However, the combination of these measures differ between the scenarios. All scenarios achieve the same level of GHG emissions, making the scenarios comparable in terms of energy, environmental and economic impacts. (European Commission, 2011a) The scenarios are summarised in the following table.

Table 9.1: Summaries of European Commission's five future scenarios (European Commission, 2011a)

Energy efficiency scenario	In the scenario, one unit of GDP in 2050 requires 71% less energy input than in 2005. The annual energy intensity improvement would have to be 2.7% annually. This would require almost doubling the improvement rate compared to historical development.

Diversified supply technologies scenario	The scenario includes acceptance of nuclear and CCS technologies as well as further RES facilitation policies. The option is mainly driven by carbon prices and carbon values (policy measures that bring about emission reductions).
High RES scenario	In the scenario, RES share reaches 75% in gross final energy consumption and 86% in power generation. The share goes up to 97% in electricity consumption when excluding losses related to pumped storage and hydrogen storage of electricity. The scenario requires high investments in RES generation capacity (reaching 1900 GW by 2050) and storage technologies.
Delayed CCS scenario	The scenario estimates the results of delaying the deployment of CCS technologies. The model assumes large scale deployment after 2040.
Low nuclear scenario	The scenario shows the consequences of low public acceptance of nuclear generation resulting in a shift toward other technological options (like CCS for fossils).

The five scenarios estimate different developments of renewable shares in electricity production. The following figure shows how RES-E generation is expected to develop under different scenarios. The scenario estimations are compared to the Commission's reference scenario 2013.

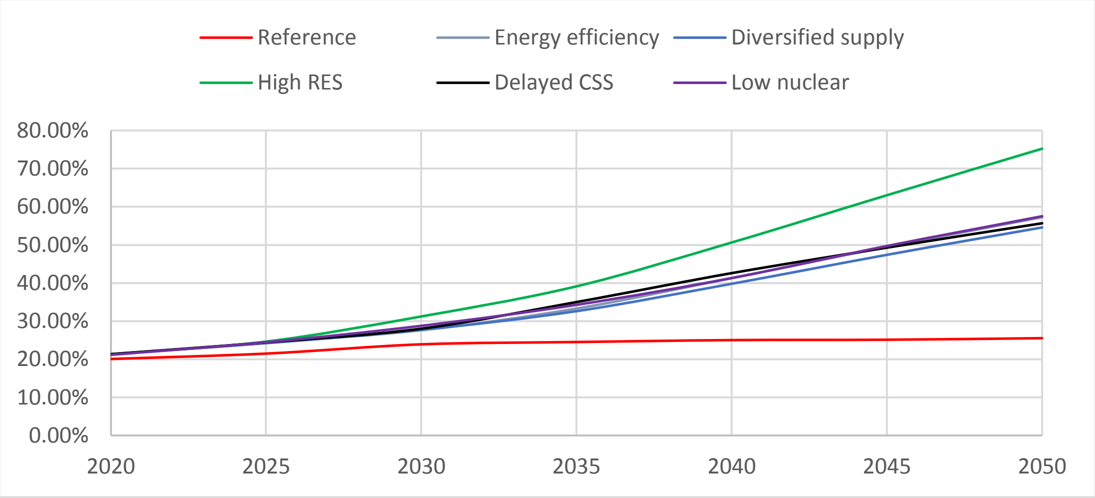

Figure 9.1: RES in gross final energy demand in different European Commission's scenarios compared to 2013 reference scenario. Data from (European Commission, 2011b)

As shown above, there is a drastic difference between the reference scenario describing the evolution determined by current state of political and economic affairs and the different scenarios designed to reach Community goals by 2050. It is clear that whichever path to GHG emissions reductions is chosen, the amount of renewable generation has to be substantially lifted from its current business-as-usual level.

Comparing estimated levels for 2030, the difference between high RES scenario and the reference (Figure 5.6: European Commission's Reference Scenario 2013 renewable electricity share in total electricity generation 2000-2050 (%)) is 7.3 percentage points (max) and 3.7 percentage points between energy efficiency and reference (min). In terms of absolute generation volumes, these differences are 267.5 TWh and 135.5 TWh respectively. The total electricity generation in 2030 is estimated to be around 3664.5 TWh (in EU27). The average deviation from the reference (for the five scenarios) is 4.7 percentage points.

For 2050, which can be argued to be slightly out of speculation’s reach, the difference between high RES scenario and the reference is huge. A deviation of 49.7 percentage points would account for approximately 2156.3 TWh of production when compared to the predicted overall generation of 4338.6 TWh. This gap also influences the overall greater deviance between the scenario-average and the reference being 34.6 percentage points. In 2050, the total costs of electricity supply are predicted to vary from EUR 100 to EUR 200 per MWh, depending on policy scenarios (European Commission, 2013c).

As mentioned before, the European Commission is currently seeking support for their proposal on the underlying energy and environmental framework for 2020-2030. Thus, for now, larger focus should be given to that particular period, bearing in mind the estimations for the following decades.

As can be seen in the figure above, renewable generation of electricity will not only grow, but accelerate during 2020-2050. Since this is true for all proposed scenarios, it can be assumed that further support is required for RES-E technologies. This statement is enforced by the widening gap between proposed scenarios and the reference, because although the reference scenario does not introduce new support mechanisms and predicts phase-out of existing schemes by 2030, the effects of the current schemes are still included in the reference curve (which is not reaching desired levels). The reference scenario can thus be interpreted so that steady growth predicted until 2050 would require, at least partial, support up until 2030, after which the development in various generation-related fields would be sufficient to support further growth. Building on that assumption, it can be stated that elevated progress would depend on the amount of support - especially during the early years of technological advancement from 2020 to 2030.

In order to broaden the view on renewable energy development during the decades to come, Commission's predictions can be put parallel to other suggested scenarios. REN21 (Renewable Energy Policy Network for the 21st Century) has gathered and analysed over 40 different scenarios. As suggested in their work, the most recent predictions (published in 2010-2012) can be divided into three main groups according to their optimism in RES development: conservative[31] (RES share of total global energy ca. 15/20%), moderate[32] (ca. 25-40%), and high renewables[33] (ca. 50-95%). (REN21, 2013)

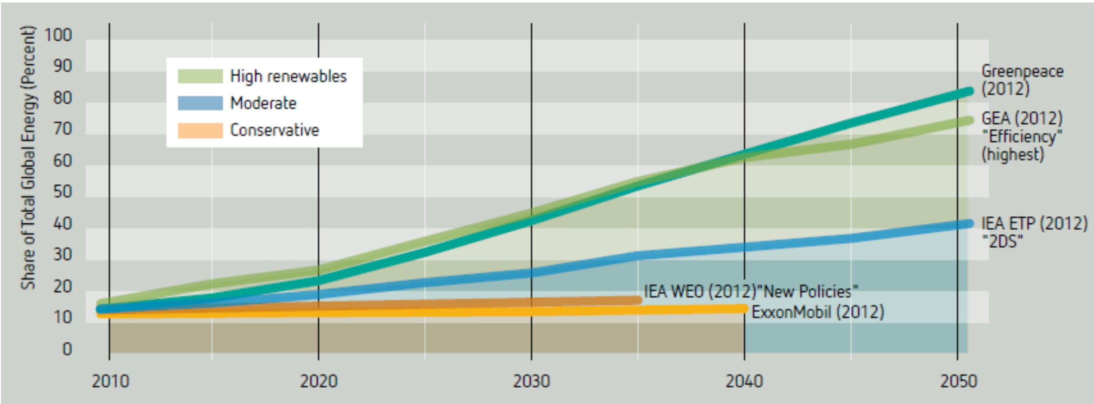

Figure 9.2: Conservative, moderate, and high renewables scenarios to 2050 (REN21, 2013)

9.2. Renewables reaching grid parities

Different RES-E production technologies are expected to reach grid parity[34] at different times. At grid parity, renewables would become as competitive as conventional production. Grid parity scenarios rely heavily on technology- and fuel-specific cost analyses, with varying amounts of integrated risk comparisons and environmental (and other) externalities.

When assessing the cost competitiveness of different technologies, a methodological question arises about the "right way" of calculating related costs and making the investment

[31] e.g. BP's Energy Outlook 2030 (2012), ExxonMobil's Outlook for Energy: A View to 2040 (2012), and IEA's World Energy Outlook – "New Policies"-scenario (2012)
[32] e.g. IEA's World Energy Outlook (2012) – "450" and "2DS" scenarios, and IPCC's Special Report on Renewable Energy (2011) (synthesising over 160 climate-mitigation scenarios)
[33] e.g. GEA Global Energy Assessment (2012) – "Efficiency"-scenario, Greenpeace's Energy [R]evolution, and WWF (2011)
[34] Point where renewable electricity costs equal the costs of conventional generation (Hernandez-Moro & Martinez-Duart, 2013)

decision. There are three fundamentally different types of comparisons: levelised cost comparison, financial risk-return comparison, and whole-energy-system comparison. (REN21, 2013)

The most commonly used comparison method is the levelised cost comparison method that accounts for direct investment costs. The method, however, often fails to address factors like fossil fuel and technology subsidies that tilt the advantage toward conventional production. (REN21, 2013) The IEA World Energy Outlook, published in 2012, estimated that global subsidies to fossil fuels exceeded US$ 520 bn in 2011 (IEA, 2012b). Many experts have called for eliminating these subsidies in order to boost sustainable development. In addition, comparisons often fail to include environmental costs of conventional production and risks from fossil fuel price swings. (REN21, 2013) The levelized cost approach also rarely takes into account the integration costs of highly intermittent generation as well as the progressively lowering rates of return of renewables[35], with a significant effect when RES technologies reach higher shares in production. (Ueckerdt, et al., 2013)

Another type of comparison often used is the financial risk-return comparison that involves the difference between a project's internal rate of return and the cost of capital, adjusted for the risks of a specific project. The results from this type of comparison may differ from the levelised cost method because of the risk-inclusion. E.g. projections for fossil generation investment costs may give higher results due to elevated risk profiles of conventional fossil fuel plants. (REN21, 2013)

Finally, cost comparisons should try to take into account the effects of the surrounding energy system. Cost analyses can be quite different for similar plants in different generation environments with distinct configuration, market rules, operation patterns, and load profiles. (REN21, 2013)

Table 9.2: Typical energy costs (LCOE) per technology (McKenna, et al., 2014) (REN21, 2014) Unit changed from US cent to euro cent using exchange rate of 2014-07-29 (1 EUR = 1.34 USD)

Technology	Typical energy costs (LCOE in € cents / kWh)
Bio-power from solid biomass	3-15

[35] The merit order effect pushes the electricity price down during high RES production periods due to minimal short term marginal costs of renewables.

Bio-power from gasification	4-18
Bio-power from anaerobic digestion	4-14 (biogas) 3-5 (landfill gas)
Geothermal power	4-10 (condensing flask) 5-10 (binary)
Hydropower	1-9 (> 20 MW) 2-17 (< 20 MW)
Ocean power	16-21[36]
Solar PV	10-25 (Europe)
Concentrating solar thermal power (CSP)	14-28 (through and Fresnel, no storage) 13-28 (through and Fresnel, 6 h storage) 9-12 (tower, high end with storage)
Wind onshore	3-12 5-15 (Germany)
Wind offshore	11-17

The above table gives a rough estimate of current LCOE for different renewable technologies. The fraunhofer institute for solar energy systems has published similar cost levels[37] for different RES technologies in Germany. They have also published figures for LCOE from conventional energy sources. Exact figures are nearly impossible to calculate, but the table below gives an example of LCOE levels with which the emerging technologies would have to compete. The following values for brown coal, hard coal, and combined cycle are given.

Table 9.3: LCOE of conventional power plants at locations in Germany in 2013 (data read from figure) (Fraunhofer ISE, 2013)

Technology	Typical energy costs in Germany (LCOE in € cents / kWh)
Brown coal	3.8-5.5
Hard coal	6.5-8
Combined cycle	7.5-9.8

By comparing the two tables above, it seems that many of the renewable technologies are reaching or have already reached grid parity. This is enforced by Fraunhofer ISE's report's prediction that LCOE for fossil production will rise before reaching year 2030 (Fraunhofer ISE,

[36] LCOE for ocean power (wave power) also reviewed in (European Commission, 2014e), where estimated value for 2020 is 20.8 € cents / kWh and average development estimated to reach ca. 15 € cents / kWh by 2035.
[37] Solar PV 0.08-0.14 €/kWh; wind onshore 0.045-0.105 €/kWh; wind offshore 0.12-0.195 €/kWh; biogas 0.135-0.215 €/kWh (Fraunhofer ISE, 2013)

2013). The data is far from conclusive, but these averages and other studies suggest that renewable technologies might soon become competitive – at least in LCOE estimations[38].

Estimations of reaching grid parity for different technologies are extremely hard to make. For example, IEA's Energy Technology Perspectives 2012 projects that onshore wind LCOE would settle between 3.7 and 7.5 euro cents per kWh by 2020 (IEA, 2012a). This would in theory be enough to reach grid parity. However, the development is highly vulnerable to factors such as generation mix of the grid, distance between wind farms, connectivity, economic incentives, institutional support, price of fossil fuels, development of nuclear power and LCOE of other RES technologies. For example, an emissions cost of US$20 / tCO_2 imposed on fossil generation would make wind power increasingly competitive compared to conventional sources. (Timilsina, et al., 2013)

Hernandez-Moro & Martinez-Duart have conducted a detailed study on solar PV and concentrating solar power (CSP) LCOE values and their future development. In their work they have found that with CO_2 emission prices of 50 $ per tCO_2, solar PV would reach grid parity between 2028 and 2038, while CSP systems would reach it between 2021 and 2026. (Hernandez-Moro & Martinez-Duart, 2013) In another study by Fokaides & Kylili, the authors conclude that in Cyprus, solar PV has already reached grid parity. This is seen as mainly due to generally higher electricity prices in insular systems. (Fokaides & Kylili, 2014)

Citi Research has globally compared LCOE of solar power to conventional production. They have found that solar power has in large parts of the world already reached parity in the residential sector[39]. This is true for e.g. Italy, Spain, Germany, and Portugal. Utility-scale parities are expected to be reached during the next decade – globally led by Japan, US, and Australia. In Europe, Germany is expected to reach utility-scale grid parity for solar in 2019. (Citi Research, 2014)

Expectations for maturing RES technologies to reach grid parity are visible in most of the future estimations. Competitiveness is expected to develop during the time of institutional support allocated to RES production, which would be phased out once grid parity is reached.

[38] Notice that although RES technologies may approach the same level LCOE as conventional production many problems still remain that prevent renewables from fully competing with e.g. fossil generation. Some of those problems are presented in previous chapters.
[39] Term used in report: "residential solar socket parity"

As pointed out above, exact LCOE estimations are very hard to make and even harder to apply generally. However, a good retrospective view on the global standing of renewable technologies, as compared to conventional production, is presented by the International Renewable Energy Agency (IRENA) in their recent publication, “Remap 2030 – A renewable energy roadmap”. The report shows that many of the renewable technologies are already able to compete with conventional production. (IRENA, 2014)

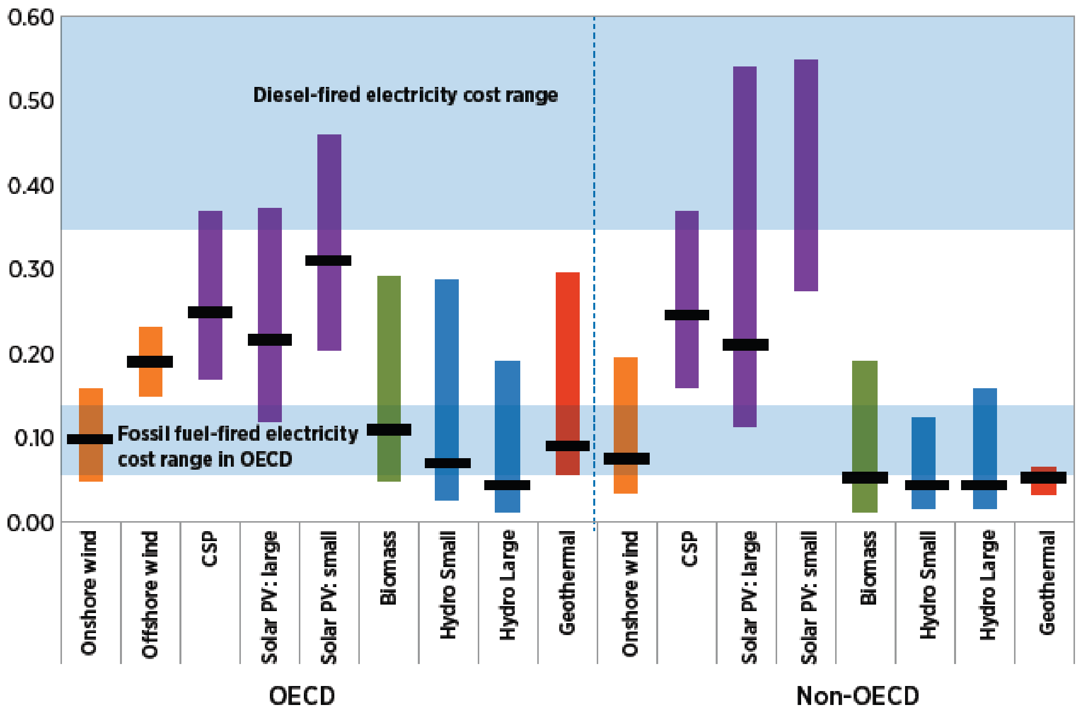

Figure 9.3: Weighted average and range for the LCOE by technology and region (with 10% discount rate) LCOE in USD(2012)/kWh (IRENA, 2014)

A different point of view is presented in work done by Hirth. The author gives a conclusion that wind and solar power will struggle becoming competitive on a large scale, even with steep learning curves, mainly because of the merit order effect. Electricity prices will be significantly lower during times of high RES generation, when large quantities of wind and solar become available. The value of wind energy will fall to 0.5 to 0.8 of a constant electricity source when a market share of 30% is reached. For solar PV, the penetration level is 15%. This would result in lower investor revenue. (Hirth, 2013) This is partially supported by Tveten et al., who have observed an average reduction of 7% in electricity prices due to solar power integration during one year in Germany. (Tveten, et al., 2013)

The possible need for support after grid parity is also touched on in work by Lund. The author suggests that an amount of “oversubsidizing” may be needed to enable a reasonably fast market take-up of a new technology with higher costs than the incumbent alternatives. This is also the case if desired technology development is greater than the typical expected market share growth. (Lund, 2014)

9.3. Lack of market power

The European Commission has strongly stated that incentives in the future, with increasing shares of renewables, have to become more efficient, create economies of scale, and lead to more market integration. (European Commission, 2011b)

As touched upon previously, it is becoming clear that at least some of the renewable technologies will reach grid parities between 2020 and 2030. However, as shown in the support volumes section, nearly all of the produced electricity from emerging RE sources, like wind and solar, is heavily remunerated. In fact there is next to zero wind and solar generation in the EU that is not supported by some scheme (Figure 8.6: Share of wind power generation eligible for support 2009-2012 (%) & Figure 8.9: Share of solar power generation eligible for support 2009-2012 (%)). The below figure presents production development for different energy sources in Europe as absolute changes in production compared to the previous year[40].

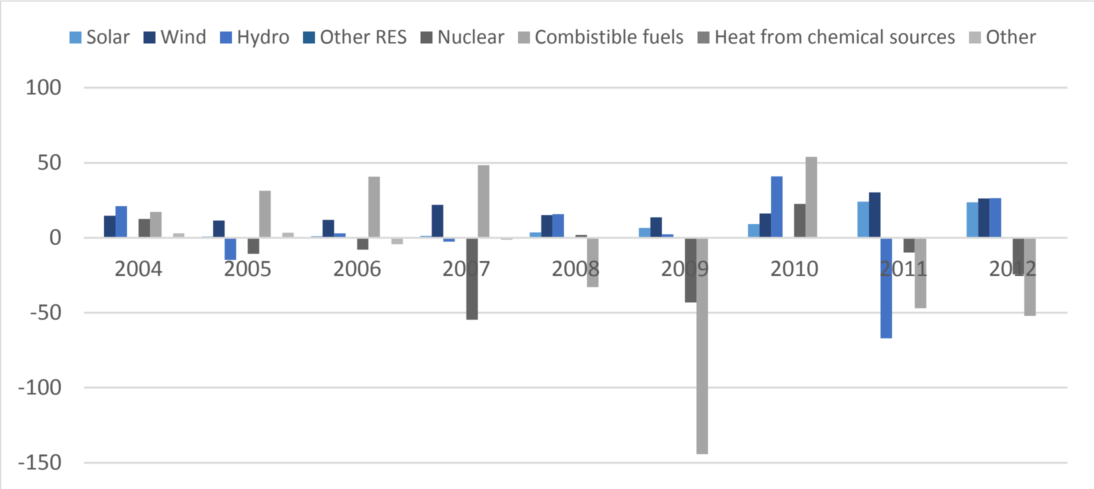

Figure 9.4: Annual changes in electricity generation (displayed year compared to previous year) by electricity source in Europe 2004-2012 (TWh) Data from Eurostat (nrg_105a)

A few things can be seen from the above figure. Most importantly, during the last few years, growth has been most significant and stable among the heavily remunerated renewables, like wind and solar. The growth has also been accelerating during the last decade. Fluctuations in hydro power generation can mainly be explained by differences in yearly

[40] Presented value = (Gross electricity generation year X) – (Gross electricity generation year (X-1))

rainfall volumes. It is also visible that production from combustible fuels and chemical sources is in a relatively heavy downfall.

Renewable production is physically integrated into the market, and large parts of its support are financed via the electricity market (costs allocated to consumers), thus renewable generation is increasingly affecting the electricity price behaviour (Moreno, et al., 2012). Therefore, RES producers should be more exposed to market signals (European Commission, 2014a).

Currently, shifting from fossil production to renewable sources will increase the industrial and household end-user prices. However, being consistent with most of the literature, a change toward market orientation with more competition would lower the overall cost of electricity production and electricity prices in both consumer types. Thus, a more market-based mechanism should be considered. (European Commission, 2014c)

During recent years (from 2007 in German intraday market, 2008 in German-Austrian day-ahead market, and 2010 in French day-ahead market) markets have occasionally experienced negative electricity prices when high intermittent renewable generation is combined with low demand. In theory, negative prices can be seen as a market mechanism to reduce oversupply during excessive production. (EPEX SPOT, 2014) However, the logic is ill-fitting when accounting for producer revenue from price-based support schemes. In an extreme but fully plausible case, the electricity producer benefits, through granted subsidies, from selling produced electricity (for which there is no demand for) with a negative price to a consumer. This phenomenon, if not constrained, is expected to become more common as renewables take up bigger shares of the market. (Nicolosi, 2010)

The shortcomings of currently dominating price-based support schemes are highly evident when assessing the market effect on renewable generation development. Another example of this is the solar energy support scheme in Spain. Spain experienced an exponential growth in solar PV capacity during 2007-2008. This was greatly a result of a generous feed-in tariff being untied from market electricity prices, although many other reasons also accelerated the growth in investments. The exponential growth triggered a parallel growth in total costs of solar PV support. Alarmed, the government was forced to constrain the expenditure growth with drastic changes in support policies, which in turn have led to a near halt in solar PV development since 2009. In addition, some retroactive measures taken led to a serious undermining of investor’s confidence. Although much can be learned from the Spanish case, the threat of similar development has also been evident in other Member States, like Germany, Czech Republic[41], France, and Italy[42]. (del Rio & Mir-Artigues, 2012) (Ortega, et al., 2013) (de la Hoz, et al., 2013)

Jäger-Waldau et al. have estimated that renewable electricity production in 2020 will be dominated by wind power and will include a large share of solar generation[43] (Jäger-Waldau, et al., 2011). Higher penetration of new renewables creates a need for other renewable-related policies that deal with problems from high intermittency. Some conventional producers, who are able to maintain grid balance with agile production technologies, may need additional support in order to stay profitable. This effect is most evident in cases where plant (e.g. CCGT) operation hours per year decrease, resulting in a higher weight of long-term marginal costs in overall electricity generation costs. An alternative for easing this issue would be the integration of European electricity grids and markets, bringing us back to the need for the internal electricity market. (Trümper, et al., 2014) (Koliou, et al., 2014) (Haas, et al., 2013) (Genoese, 2013)

The European Commission has clearly stated that renewable energy producers should be increasingly exposed to market prices. (European Commission, 2012b)

9.4. Impact of electricity market integration

The Member States have committed to completing the internal electricity market by 2014. For it to work properly, it is important to define the role, level, and nature of public intervention. The amount and nature of the intervention should be in line with principles of subsidiarity at a Union, regional, national, and local level. The Commission urges public interventions to be made consistent throughout the Community. (European Commission, 2013c) The RES directive introduces joint support schemes as one of the three intra-European cooperation mechanisms[44]. (Klessmann, et al., 2010)

Ill-designed intervention without proper co-ordination risks being counterproductive and distortive to functioning of the internal electricity market. (European Commission, 2012a) The Commission has in its Action Plan for Europe defined the plausible properties of state-

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[41] Introducing limits for renewable subsidies in 2010 after explosive growth in remunerated capacity
[42] Introduction of a cost cap of EUR 6 bn for solar PV in 2012 and similar caps coming into force for other technologies in 2013
[43] Shares of different technologies in total RES electricity production in 2020: wind 41.3%; hydro 29.3%; biomass 19.4%; solar 8.6%; geothermal 0.9%; marine resource 0.5%
[44] The three intra-European cooperation mechanisms are: statistical transfers, joint projects, and joint support schemes. (Klessmann, et al., 2010)

level interventions to ensure the success of the internal market initiative. The Commission has also published its views on renewable support schemes in the 2013 document "European Commission guidance for the design of renewables support schemes." Until now, Member States have announced significant public support investments in new generation capacity. These uniquely designed schemes may, however, lead to distortions of competition and investment signals. (European Commission, 2013c) By 2011 only six European countries had integrated the use of cooperation mechanisms into their national renewable energy action plans (NREAPs) (Beurskens & Hakkenberg, 2011). Nevertheless, cooperation activities could become the next trend in the development of European renewable support. There are several cooperation mechanisms already in action (e.g. Swedish-Norwegian Elcertificate system) or planned (e.g. joint project between Ireland and UK) (Klessmann, et al., 2014) (Kitzing, et al., 2012). It should be taken into account though that not all research supports the integration of renewable support schemes. Toke has stated that broad opening of a support scheme (British Renewable Obligation (RO) used as an example) to cover Europe as a whole might cause a significant drop in renewable investments. This is explained by investments being place-specific. In other words, the public is more often than not more interested in local investments than investments in another region or country. (Toke, 2007)

In his article, Buchan argues that renewables could be promoted at lower cost if Member States subsidised in the same way. This would also diminish the risk to electricity market integration, and it would also hold true in the case of different national subsidy levels. (Buchan, 2012)

10. Adaptation capabilities of different support schemes

Comparing the Union's 2013 reference scenario and a variety of suggested paths of development by the Union and other stakeholders, it becomes clear that current measures in promoting renewable energy sources (among other environmental actions) fall short in reaching desired effects. Especially in scenarios that predict high growth rates for renewables, the gap between the reference and the objective is huge. Support is also needed to counterbalance the negative externalities and market disturbances by beneficiaries of fossil and nuclear energy (Hinrichs-Rahlwes, 2013). This indicates a further need for development in the field of renewable energy support.

This chapter tries to assess different support schemes in the light of previously covered drivers of change and volume developments.

10.1. Requirements for a robust support scheme

Before assessing individual support schemes, it is good to sum up the requirements set for future support mechanisms. These requirements are briefly presented in the earlier parts of this thesis, or stem from the estimated development paths above.

During the period of renewable promotion, the support schemes have had to push levels of renewable capacities, often from zero (when excluding large hydropower), to currently agreed on 2020 levels. A collective 20% RES share will be reached through national targets varying roughly from 10 to 40 percent. The only exceptions have been the Scandinavian Sweden and Norway with significantly higher targets. Post-2020, the situation will be quite different. The volumes of renewable production will be on a totally different level, and pushing the development further from currently set 2020 targets to long-term objectives of 2050 will require dealing with exponentially larger volumes of intermittent renewables.

The new level of capacity will also result in a completely new level of financial burden to the supporter. In many countries, the public tolerance toward huge support levels is growing weak, especially where the burden is borne directly by the public (Buchan, 2012) (EUROPEX, 2014a). The new support schemes will have to be more flexible and efficient to successfully channel the right amount of funding to the right technology. Hence, it is increasingly important to have a support design where cost-efficient allocation of resources is still possible (Spiecker & Weber, 2014). This is underlined, when results about the need for oversubsidizing by Lund are taken into account.

Demand for efficiency will most probably lead to a development toward more competition - between different renewable technologies as well as renewables and conventional production. The Commission has raised a need for future support schemes to be more exposed to market forces (European Commission, 2013b). A wider variety of responsibilities, such as participation in balancing markets and tighter restrictions on priority dispatch, are expected to be imposed on renewable producers. The previous two resulting indirectly in higher levels of investment risks.

The investments in wind power in 2013 decreased by 8% compared to 2012. The development is mainly explained by the current destabilised legislative framework for renewables as well as market, regulatory and political uncertainty sweeping across Europe. (EWEA, 2014)

Investment risk will have to be managed mainly by long commitments and transparent policies and mechanisms – statement holding true for support mechanisms universally. However, as the requirement for market unification is introduced, risk can also be managed by increasing the market volume (Raadal, et al., 2012). Thus, the new support schemes should be compatible with the internal electricity market act, which in many cases is an essential goal in the field of energy.

As electricity markets integrate and international imports and exports start to dominate over national production, there will probably be a tendency to unify currently national support mechanisms (Kitzing, et al., 2012). This would prevent the formation of barriers to free movement of goods as well as drive down the risk of overburdening national budgets. Therefore support schemes are strongly incentivised to develop through more common guidelines that would ensure the compatibility among Member States as well as with the internal electricity market.

The following segments will compare the adaptation capabilities of price- and volume-based support schemes to meet above-mentioned requirements. However, on a more general level, Lean & Smyth have concluded that policies that promote annual increase in renewable electricity generation (production-based support) will be more effective than policies designed to give a fixed amount of remuneration in a limited time (investment incentives and tax credits). (Lean & Smyth, 2013)

10.2. Price-based support schemes

Here, price-based support schemes cover different implications of feed-in tariffs (FITs) and feed-in premiums (FIPs).

FITs, and later introduced FIPs, have historically been very successful in attracting renewable energy investments. The main reason for this is the low considered risk premium. It can also be argued that as FITs have often been implemented with technology-specific support levels, FITs have included certain amount of flexibility. (Held, et al., 2014) Work by Dong shows that, according to empirical research, historically FIT and FIP systems have been more effective in promoting wind power capacity development compared to renewable portfolio standards. (Dong, 2012) However, when moving from marginal levels of market penetration (the pre status quo situation) to more mature technologies, research indicates that FITs may offer only little extra marginal incentive compared to a reference situation with no FIT, although the initial high effectiveness of FITs with embryonic technologies is confirmed. (Jenner, et al.,

2013) This is partially backed by empirical research by Dong that found no significant difference between wind power development in FIT and RPS systems after 2005. (Dong, 2012) This led to a speculation that fixed-price remunerations, like FITs and FIPs, are effective when applied to technologies in their early stages, but lose their superiority as technologies start to mature.

The IMF's estimation of support value growth from EUR 27 bn to EUR 46 bn in an FIT-dominated Europe in just two years (2010-2012) gives an example of the support volume growth rate, paralleled to a one percent growth in renewables in gross final energy consumption during that time (Figure 5.4: EU-28 renewable energy in gross final energy consumption. Data from Eurostat (t2020_31)) in countries where 22 out of 27 use FIT or FIP systems (Table 7.1: Combinations of primary and secondary instruments for RES-E deployment support in the EU.). At least some of these countries have also heavily burdened their consumers in financing this growth in costs. E.g. German consumers had to pay a EUR 62 per MWh levy dedicated for RES promotion in March 2013, when the electricity wholesale prices were around EUR 30 per MWh. (EUROPEX, 2014a)

Alagappan et al. have also concluded in their study, covering 14 different electricity markets, that although implementing FIT has been highly effective, it has come with very high costs. They add that while implementing such systems may lead to higher penetration of renewables in the short run, their high cost to ratepayers can threaten the economic sustainability in the long run. (Alagappan, et al., 2011)

The example of Spain should also be considered when assessing the future of renewable support schemes and considering the risk premiums related to different support schemes. As described before, Spain experienced an exponential growth in solar PV investments during 2007-2008. During that time, investors' demand for risk premiums was not elevated, because the soon-to-follow collapse of the system was not expected. The development of solar PV in Spain came to a near stop because of tightened support restrictions, but also because of the lost investor confidence. (Ortega, et al., 2013) (del Rio & Mir-Artigues, 2012) When looking at the solar power production levels and the related support developments (Figure 8.8: Solar power share in overall electricity generation 2009-2012 (%) and Figure 8.9: Share of solar power generation eligible for support 2009-2012 (%)) it can be argued that some European countries are in danger of falling into the same uncontrollable turmoil that Spain is still struggling to get out of.

The developments in Spain were extremely rapid. Similar developments, even at significantly lower pace, would pose a threat on existing systems, since countries have often made long-term commitments to investors within the price-based systems that are extremely stiff in adapting to sudden technological or financial changes regarding e.g. technology's competitiveness[45].

Research by Fagiani et al. presents a risk-based assessment of the cost-efficiency and the effectivity of FIT schemes compared to certificate systems. In their work they have found that FIT performance is very closely tied to precise price setting. If the price level is exactly right, FITs outperform quota systems. However, in practice, the determination of right remuneration levels is very difficult, and needed corrections to support scheme prices can be hard to apply. Fagiani et al.'s work is also one of the most recent confirmations to previous claims, first made by Weitzman and later confirmed by Menanteau et al., that in situations where the technology-specific marginal cost curve is flat, the price-based support system would lead to high uncertainty in production quantities and thus be inferior to quantity-based alternatives. This seems to be the case for analysed Spanish power sector and the same analogy can also be applied to other countries with similar generation environments for renewables. (Fagiani, et al., 2013) (Ringel, 2006) (Menanteau, et al., 2003) (Weitzman, 1974)

FIT and FIP systems are usually financed through adding levies and taxes to consumer-paid electricity prices. As amounts of support are expected to grow, a question about implementation of the polluter pays principle arises within the price-based systems. The EU has stated that the negative externalities of conventional production should be covered by the fossil producers. In current support implementations this requirement is often not addressed.

Fixed feed-in tariffs are least compatible with the principals of liberalized markets. FIT schemes effectively decouple renewable plants from the requirements and signals of the electricity market. From the investor's point of view there is also no motivation to reinitiate this bond in feed-in tariff systems. (Held, et al., 2014) Without incentives for efficient integration and respective control mechanisms, the indirect costs to public might become unreasonably high (Klessmann, et al., 2008).

[45] In the case of solar PV, investment costs have decreased by 80% in just 5 years, from 2009 to 2014 (EUROPEX, 2014a)

Feed-in premiums in turn are a more market-oriented[46] versions of feed-in tariffs. By allowing market prices to influence part of the revenue, the system becomes more aware of the market signals. FIPs can thus be viewed as a better suited option for coexisting with the internal electricity market. However, when choosing FIP for remuneration, the main advantage of price-based systems, the minimised investment risk, is partially lost. (Held, et al., 2014) Additionally, analysis on German market premium suggests that feed-in premium might not be sufficient to improve the market and system integration of renewable energies. On the contrary, the management premiums introduced in the German scheme have given rise to significant windfall profits. (Gawel & Purkus, 2013)

Implementing FIT/FIP systems parallel to fully opened electricity markets would lead to competition between renewable producers, as consumers would opt for the cheapest option. Producers would have competitive advantages in cases of high tariff levels, favourable generation locations, or very unambiguous aims for the increase of renewable energy sources. This standing could cause a race to the bottom of environmental effectiveness or to the top of tariff prices. (Ringel, 2006)

10.3. Volume-based support schemes

Here, volume-based support schemes refer to implementations of certificate-based quota obligations.

Volume-based systems have historically been less effective in promoting renewable capacity growth. This is most often explained by relatively higher investment risk premiums. Investors allocate higher risk factors to quota systems because with double markets (electricity market and certificate market) income levels fluctuate as a result of developments in both markets. (Held, et al., 2014) Work by Fagiani et al., however, explains that with low or moderate investor risk aversion, the quota system would perform better than a FIT system. The results also show that this outperformance is even greater with higher social discount rates[47] applied to future cash flows. (Fagiani, et al., 2013) Volume-based support schemes, namely the

[46] The level of market orientation can significantly vary. Depending on the premium being fixed or flexible, having a cap or a floor prices, as well as the time intervals between reviews and adjustment measures.

[47] The Social Discount Rate (SDR) typically functions as a parameter in Cost-Benefit Analyses (CBA) concerning the larger society that have long-term impacts. It is used to effectively compare different government investment scenarios over time. Usually SDR is constructed to involve different parameters reflecting theoretical issues (e.g. the relative importance of future benefits, the proper attitudes toward risk, the uncertainty about what the future holds, and the potential inequality between members of current generations and future ones). (Kelleher, 2012)

Renewable Portfolio Standards (RPSs) in the US, have often been criticised for being ineffective, e.g. (Carley, 2009). A widely accepted and quoted article by Yin & Powers explains that these conceptions are often inaccurate because of oversimplifications and generalisations in scheme modelling. Their more accurate model shows that on average, RPS policies have had significant and positive effect on renewable energy development. (Yin & Powers, 2010)

As argued before, comparison of the reference scenario to the scenarios reflecting the desired developments indicates that ambitious support schemes are also needed in the future. Even more so when accounting for the possible need for oversubsidizing (Lund, 2014). In practice, this would mean higher targets for renewable generation. As reviewed in the previous chapter, (10.2) Fagiani et al. have found that quota systems tend to perform better with higher set quotas as well as with flat marginal cost (as a function of installed capacity) curves which would be typical for systems where ambitious targets were pursued in the most cost-effective manner[48] (Fagiani, et al., 2013).

Probably the most challenging obstacle in using quota systems as a future mechanism of renewable support is the higher level of risk aversion and thus required premiums. This handicap can, at least partly, be offset by growing certificate markets. This would stabilize the certificate price with added market liquidity and thus scale down risk premiums (Raadal, 2010). It would also create a more promising environment for derivatives trade, which could help actors hedge related risk. Market growth is expected if the harmonization of support mechanisms would be realized, as depicted and underlined by the Commission.

The greatest asset of quota systems is the high compatibility with market principles. Quota systems fit best with the Community's goals toward single electricity market. Also, as renewable shares in the market become more significant, RES producers should bear more responsibilities related to market stability and control. A market-based approach in support systems would greatly contribute to such goals. As quota certificate systems function on separate markets, the system is robust to changes in electricity markets, and is relatively easy to expand to cover multiple Member States – as is already the case in common Elcertificate scheme in Sweden and Norway.

[48] Cost-effectiveness would be achieved by first exhausting, at least for a large part, the potential of more mature technologies (e.g. wind and solar).

Klimscheffskij has pointed out in his work that quota systems do not only promote renewable generation but also demote conventional fossil alternatives (Figure 7.5: The effect of TGC on renewable and other electricity production. Based on). This is a result of having conventional producers buy the certificates and thus fund the overall remuneration. (Klimscheffskij, 2011) In other scientific work, this crucial aspect is left with little notice when assessing the overall costs of the support schemes. Being in line with the Community-level polluter pays principle, quota systems can therefore be argued to be morally superior to publicly funded price-based systems.

10.4. Assessment results

As Ringel and Fouquet have pointed out, the final model for renewable support will probably not be a one-for-all solution (Ringel, 2006) (Fouquet, 2013). A decision between price- and volume-based schemes will only be the first generic decision paving way for more detailed implementations. The overall success of the European renewable energy promotion will depend on the success of these more detailed decisions in reflecting the true needs of the followed development paths. (Ringel, 2006) There is also no constraint to implementing only one support mechanism. As reviewed in work by Kitzing et al., combining, or "stacking", support instruments is becoming increasingly common in support implementations (Kitzing, et al., 2012).

This study recommends that in the future, renewable support schemes should evolve toward more volume-based mechanisms. Price-based feed-in tariffs and premiums definitely have their place in promoting emerging and small-scale technologies[49] – they offer a time of operation with practically non-existent risk for actors that would otherwise confront unbearable competition. However, the field of renewable electricity generation has already evolved to such an extent that more mature technologies, like wind and solar, need to be more exposed to market signals. This need is most obviously driven by the envisioned growth in renewables volumes and market integration, resulting in new kinds of features on both financial and technical sides.

Research shows that as renewable volumes grow, due to technology maturity and competitiveness, price-based support schemes start to lose their advantage over quotas in attracting new investments. This is quite the opposite in the case of volume-based schemes,

[49] There is already a tendency in Europe to more often support smaller installations with feed-in tariff that larger ones (Kitzing, et al., 2012).

where the growing market shares contribute to certificate market liquidity and reduce investment risk, resulting in better investment environments.

High renewable targets are also cost-efficiently reached with volume-based support schemes (Aune, et al., 2012) (Aune, et al., 2008) (Haas, et al., 2004) (Bye, 2003). This is mainly due to the fact that markets tend to favour growth where it’s most affordable, but also because of the reviewed results of quotas performing better with higher targets and in cases where the marginal cost curve is flat. The latter is mainly explained by quota systems’ tendency to promote the usage of the most cost-efficient potential first and the policy’s ability to accurately fulfil targets even in cases of small differences in marginal costs of investments.

A separate certificate market, as introduced by volume-based schemes, is also a more robust and agile alternative to government-maintained system, which is often seen as rigid and prone to lobbying[50]. Even in cases of good policy learning (e.g. the German FIT scheme for solar PV) a policy intervention, solving one issue, changes the socio-technical system so that new issues emerge, leading to a continuous cycle of inducing and reacting (Hoppmann, et al., 2014). As discussed before, a certificate market would also be a better solution in allocating support costs to initial polluters, making them responsible for their negative externalities and easing the stress on final consumers.

In the case of Germany, this thesis does not stand alone in recommending a transition towards a volume-based support. In 2013, the German Monopolies Commission has, in its special report, urged the government to amend the Energiewende[51] by proposing a support remodelling in accordance with the Swedish Elcertificate quota system. The reasons behind the proposal are similar to the ones presented in this thesis, e.g. the current policy’s efficiency deficits, over-compensation, market distortions, and heightened costs. The Monopolies Commission expects the quota system to perform better in avoiding costly over-achievement, matching the support volume to the needed remuneration, and preventing subsidising production during negative electricity prices. (The German Monopolies Commission, 2013)

[50] In their study Marques et al. have argued that the lobby of the traditional energy sources has hindered renewable development and CO_2 reductions. (Marques, et al., 2010)
[51] “Energy Turnaround”, a German venture to change the country’s energy policy and infrastructure towards a more sustainable solution. Implemented largely via the German Law on renewable energies (EEG)

With strong incentives from the Union to complete the internal electricity market, a market-based support system (e.g. quota) would better accompany the internal electricity market. The potential of integrating support schemes across the EU is also greater with volume-based systems.

As a reference, similar development of support schemes has been proposed by Schröder in 2010. The below figure shows the recommended transitions between support schemes as compared to technology deployment and maturity. (Schröder, 2010)

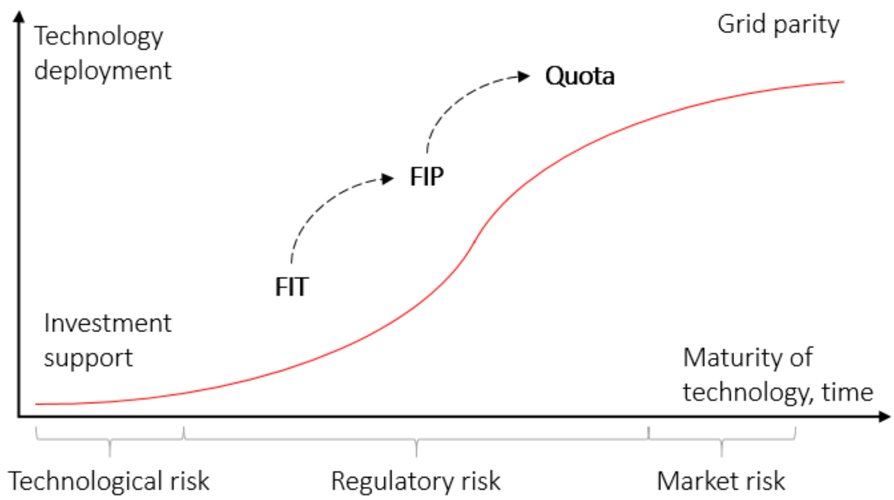

Figure 10.1: The fitting support scheme for technologies at various stages of development. Based on (Schröder, 2010)

11. Multilateral Tradable Green Certificates

Building on the previously stated preference to evolve renewable energy support toward volume-based systems, this chapter discusses the option of expanding and harmonizing a volume-based scheme to cover multiple Member States as well as the potential benefits of opening the support to voluntary participation.

The motivation toward Member State cooperation is expressed in the Directive 2009-28-EC, a.k.a. the RES Directive. It states that "Member States should be encouraged to pursue all appropriate forms of cooperation in relation to the objectives set out in this Directive. Such cooperation can take place at all levels, bilaterally or multilaterally." The Directive presents three main cooperation mechanisms between Member States with effect on target calculation and target compliance: statistical transfers[52], joint projects, and joint support schemes. (European Parliament and Council, 2009a)

11.1. Transition to Multilateral Tradable Green Certificates

As renewable energy technologies mature, they can be expected to become more market-oriented. As discussed in this thesis, this evolution should lead to a change in associated support schemes, changing from institutional price-based implications toward more market-based volume-based systems, which would finally lead to complete competitiveness and grid parity.

There is a very limited amount of empirical data available about volume-based renewable energy support during the technological maturity between the end of the initial embryonic phase and the final grid parity. This is in many cases natural, since renewable technologies are mostly still emerging and in cases of further development the changes in support schemes are lagging behind or are politically still unwanted[53]. However, there are some examples to study, namely the bilateral support scheme between Sweden and Norway, as well as the theoretical basis for comparing closed national support against a multilateral approach.

This chapter mainly builds on previous work by Aune et al. (2012), Söderholm (2008), del Rio (2005), and Mozumder & Marathe (2004). They have successfully demonstrated the effects of a multilateral approach in implementing a Tradable Green Certificate (TGC) market. Söderholm has additionally discussed the Swedish-Norwegian case.

The current mechanism of allowing a Member State, with high marginal cost curve for renewables, to fulfil its target more cost-efficiently in another Member State is the statistical transfer as introduced by the RES Directive. This option is, however, in low use, with only less than 1% of the renewable production being traded. (Aune, et al., 2012)

A multilateral TGC system would fully exploit the benefits of a cost-effective distribution of renewable energy production. In the system, all producers would receive a green certificate

[52] Member States may meet their national renewable targets by funding renewable energy production in other countries.

[53] It can be argued that the shortcomings of price-based support schemes are currently just emerging as renewables are being increasingly deployed. Thus drivers of change are still inferior to the desire to remain in status quo, which is often backed by past statistics showing clear success of price-based mechanisms (as can be expected when considering the maturity-stage of observed technologies).

for each unit of renewable electricity generated. All suppliers[54] would then be obligated to purchase these certificates corresponding to their countries' specific shares of renewable energy. (Aune, et al., 2012) Common markets would not suffer from individual price restrictions, introduced to mitigate investor risk, but common floor and ceiling prices would be preferable, since the lowest ceiling and the highest floor would dominate in a well-functioning market. (Mozumder & Marathe, 2004) It should be kept in mind though that for the time being, the demand on this market would be completely policy driven. (Söderholm, 2008) The market would follow the same principle, as shown in Figure 7.6: Supply and demand curves in competitive TGC markets. Based on, for market actors in achieving cost-effectiveness. (del Rio, 2005)

The multilateral TGC system can be initiated by only few participants, as in the case of the bilateral system between Sweden and Norway. It would then provide benchmarking opportunities for other possible participants. However, it can be argued that having only few members makes the system vulnerable to political or financial changes in one of the countries. Thus, in the long run, it would be essential to damp these effects by including more countries. It is equally important to establish long-term energy policy stability and common understanding of the underlying goals within Member States in order to secure the well-functioning of the market. (Söderholm, 2008)

Aune et al. have compared three scenarios[55] in order to determine the possible effects of multilateral trade vs. national trade and EU-level targets vs. national targets. Using their theoretical model, they found that the EU-wide target for renewables is more cost-effective than implementing national targets. This holds true with or without a multilateral trade option. Overall cost-effectiveness was found to be best in the scenario of a common renewables target and allowing free certificate trade. It was also found that efficiency in total production of renewable energy would be better if multilateral trade is allowed, regardless of target distribution. (Aune, et al., 2012)

Aune et al. have used the model to estimate the potential savings in reaching the 2020 targets if EU-wide TGC system would be applied. In their results, they approximate that 70%

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[54] Alternatively fossil producers or suppliers can be obligated to purchase the certificates. This leading to additional drop in conventional generation. (Klimscheffskij, 2011)

[55] i) a common renewable target for all member states with EU-wide trade in green certificates, ii) differentiated national targets for each of the member states with EU-wide trade in green certificates, and iii) differentiated national targets for each of the member states with domestic trade in certificates only

of the overall cost of achieving the EU's renewable target could be cut. This is the result obtained by comparing the scenario with national targets and no multilateral trade to two other options. Assessing a set of countries individually shows that the overall savings are significant and positive. Countries with high potential for renewable generation at low cost, e.g. Sweden, Norway, and Finland, would benefit the most. Almost all countries would experience significant cost reductions. However, negative effects also occur. This is mainly due to certificate trade's effects on equilibrium prices of all energy sources. E.g. Spain could experience a slight growth in costs because of large imports of more expensive gas. (Aune, et al., 2012) Del Rio has also found that a harmonised TGC system would promote target achievement, result in significant cost reductions and lower the market price of the certificates, resulting in lower electricity prices. (del Rio, 2005)

As reviewed before, smaller certificate markets are potentially vulnerable to strategic behaviour of large market actors (Tanaka & Chen, 2013). In the case of a European market, this risk would be significantly reduced due to increased market size.

In their study, Aune et al. also conclude that it would be more important to establish a common TGC market in Europe than introducing a common national targets in the context of lowering overall costs. (Aune, et al., 2012) Compared to fragmented markets, a harmonised TGC market would contribute to price stability, since some small national markets would be incapable of smoothing the intermittency-caused fluctuations. (del Rio, 2005) (Raadal, 2010)

11.1.1. Market effectiveness and policy legitimacy

An open TGC system that allows international trade between participating states is, at least theoretically, the most cost-effective way to support renewable energy sources and promote their development. The system also follows the equimarginality principle in national target achievement. (Aune, et al., 2012) (Söderholm, 2008) (del Rio, 2005) However, as both lay people and politicians tend to favour local benefits of green production, there is a potential conflict between efficiency and political legitimacy. It will become increasingly important to stress the benefits of the support system from an international point of view. It should be underlined that local impacts of green electricity production are always secondary benefits and should not provide the prime motivation for support allocation. (Söderholm, 2008) (Mozumder & Marathe, 2004)

Involved TGC implications would also become more politically legitimate if they were harmonised to a great extent. This would include agreeing on energy sources eligible for TGC support, common standard for claiming the certificates, and at least partial common quota setting. It may also be reasonable to harmonise relevant primary policies, (Söderholm, 2008) (del Rio, 2005) (Mozumder & Marathe, 2004) although it is probably not necessary to harmonise all policy conditions for green electricity (Söderholm, 2008).

11.1.2. Swedish-Norwegian Elcertificate system

The common Norwegian-Swedish electricity certificate market has been operational since January 2012. It was based on the Swedish quota system, which had existed since 2003. The countries have a common goal of raising renewable energy production by a total of 26.4 TWh by the year 2020, which will fulfil their nationally set targets (Figure 5.1: Share of renewable energy in % gross final energy consumption in 2012 compared to national 2020 targets). Both countries are responsible for financing 13.2 TWh in the certificate system, regardless of where the new production capacity is installed. Up until 2035 this would result in an overall production of 198 TWh of renewable electricity. (Energimyndigheten & NVE, 2013) (NVE, 2014)

The functioning of the market is shown in the figure below. Electricity producers first receive one electricity certificate (Elcertificate) for each MWh of renewable electricity produced (1.). The producers receive extra income from selling the certificates in the electricity certificate market, where supply and demand determine the price[56] (2.). Demand for electricity certificates is created by electricity suppliers and some electricity end consumers being obligated to buy the certificates corresponding to a certain quota of their electricity sales or usage (3.). Suppliers then sell electricity to the consumers containing the price of the certificate (4.). Each year a quota-obligated body must cancel[57] the correct amount of certificates to fulfil its quota (5.). (Energimyndigheten & NVE, 2013)

[56] Price changes allowed within the limits of floor and ceiling prices.
[57] The term “cancel” refers to the final use of a certificate to fulfil relevant quota resulting in certificate being removed from the market.

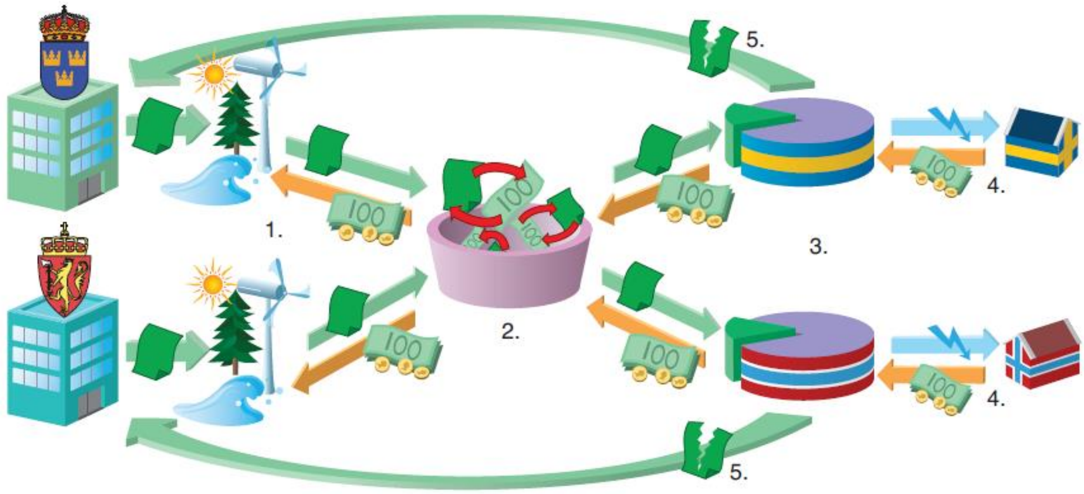

Figure 11.1: Illustration of the electricity certificate market of Norway and Sweden (Energimyndigheten & NVE, 2013)

The national quotas for both countries are presented in the following figure. The compliance rate in the system has been extremely high – in 2012 the quota obligation fulfilment rates were 99.95% and 99.97% for Sweden and Norway respectively. The high compliance rate is driven by set quota obligation charges (penalty system) per electricity certificate that had not been cancelled. The penalty rate, set as a multiple of the average certificate price, was SEK 297.86 (EUR 32.33[58]) per unfulfilled MWh. (Energimyndigheten & NVE, 2013)

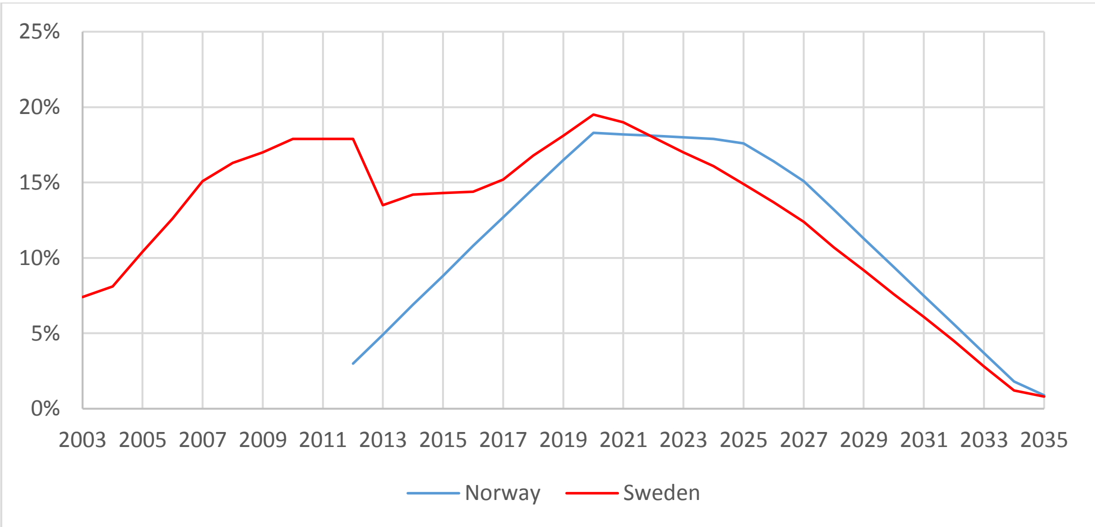

Figure 11.2: Quotas for Norway and Sweden (Poblocka, 2014) (Energimyndigheten & NVE, 2013) (Stortinget, 2011)

In 2013, a total of 16 431 992 Elcertificates were issued (920 951 in Norway, 15 511 041 in Sweden). The average price of a certificate in 2013 was EUR 22.08 with maximum monthly

[58] Exchange rate of 2014-08-06

average of EUR 24.26 in February and minimum monthly average of EUR 19.39 in June. (Statnett, 2014)

The bilateral electricity certificate market is a relatively new mechanism. Thus, in their first common performance report, the national authorities of Norway and Sweden mainly present the new system and the first year figures. The first official review of the scheme will be carried out before the end of 2015. (Energimyndigheten & NVE, 2013) However, in Sweden, the certificate-system has been in use since 2003. The statistics of issued certificates in the figure below show the development of renewable technologies under remuneration. The overall development has been highly positive. Wind power has experienced the most rapid growth rates, as is expected due to relatively low marginal costs. Biomass has also grown, especially during 2008-2011. The sudden drop in issuing volumes in 2013 was a result of older Swedish plants (ca. 1 450) becoming ineligible for support by end-2012 (Poblocka, 2014) (Energimyndigheten & NVE, 2013). This phase-out has been criticised by Fridolfsson & Tangeras to be inefficient, since inexpensive old renewable electricity is crowded out by costly new production (Fridolfsson & Tangeras, 2013).

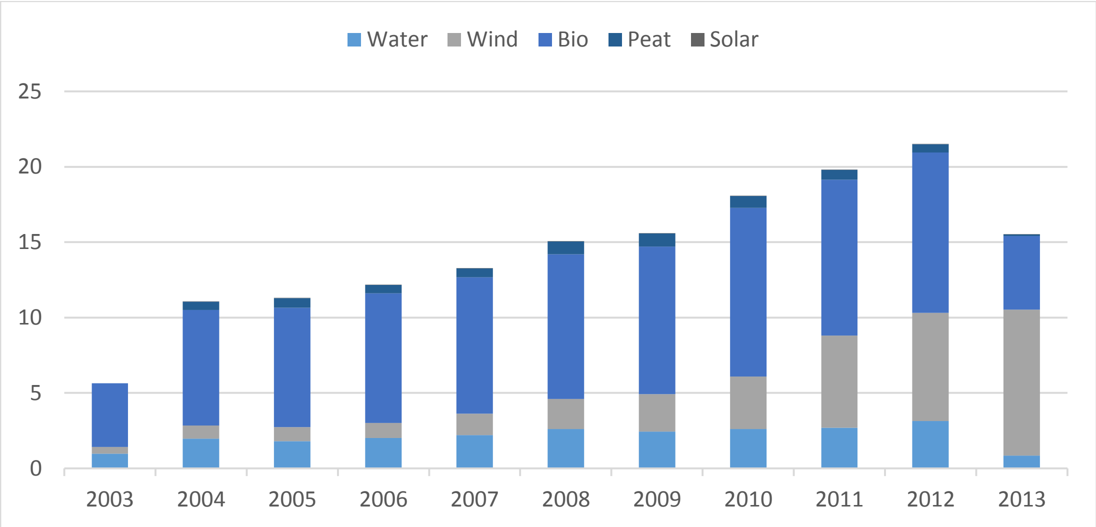

Figure 11.3: Issuing statistics for Sweden 2003-2013 (TWh) (Svenska kraftnät, 2014)

As mentioned before, the volatility of certificate prices is one of the main factors increasing risk premiums. In their work, Fagiani & Hakvoort have argued that regulatory changes by Swedish national authorities have had negative effects on Elcertificate price volatility. They have identified two breaks[59] in the analysed period relating to regulatory changes in the

[59] 8.-15.3.2010: Governments proposal to adjust the certificate quota together with the presentation to implement a joint market with Norway; 5.-12.9.2011 End of the political process to initiate a common electricity certificate market with Norway

Swedish certificate market. After finding and accounting for connections between different commodity markets showing that equity market volatility has an effect on the certificate market that volatility and electricity market fluctuations does not, the results confirm that regulatory changes have caused higher volatility periods during 2010 and 2011. (Fagiani & Hakvoort, 2014) These results are essential in possible expansions of the certificate market, as they underline the importance of political transparency and consistency.

As recommended by Fagiani & Hakvoort, we have further analysed the certificate price development on the bilateral Elcertificate market. We have found that the increase in certificate prices until the early-2013 has changed to a modest average decline leading to same price levels as within the previous Swedish system, which was predicted by the Swedish Energy Agency in 2010 (Energimyndigheten, 2010). The 2012 price development can partly be explained by the size of the certificate surplus and the rate of expansion (Energimyndigheten & NVE, 2013).

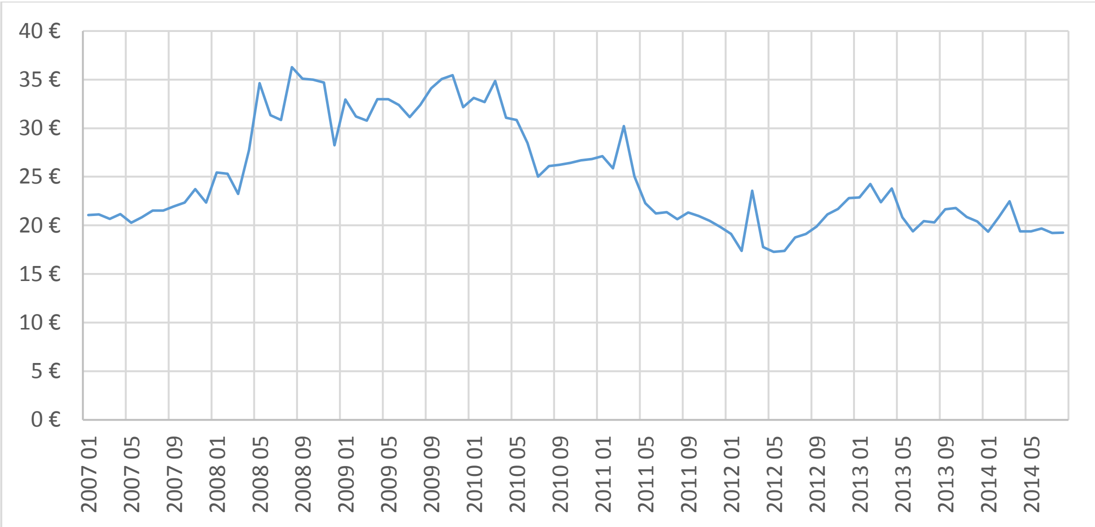

Figure 11.4: Elcertificate price monthly development from 2007-01 to 2014-08 (Svenska kraftnät, 2014)

Actors are obligated to provide the agreed price per certificate at the time of the certificate transfer. Prices, reflecting the market status, can be agreed upon beforehand. Thus, it is often better to compare yearly average prices of Elcertificates.

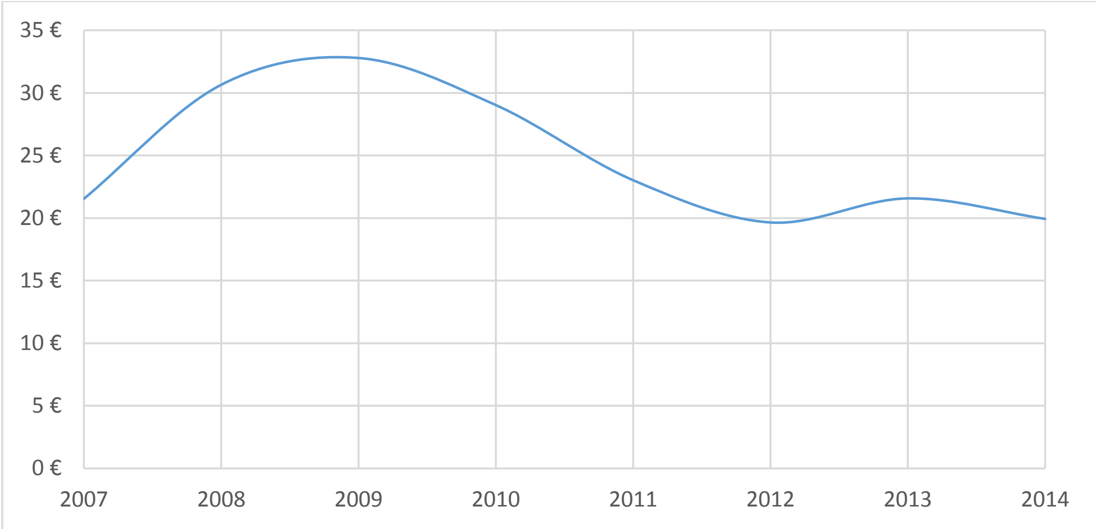

Figure 11.5: Elcertificate price annual development from 2007-01 to 2014-08 (Svenska kraftnät, 2014)

Sweden, Denmark and Austria have facilitated the largest increases in shares of renewables between 2004 and 2012. Sweden, among the first, has already reached its national 2020 renewable energy target of 51.0% in 2012. (Eurostat, 2014)

11.1.3. Opposing remarks in literature

Introduction of a European TGC system is far from a new concept. A common certificate system (based on guarantees of origin) was originally proposed by the Commission as part of the RES Directive (Turmes, 2008). At the time, the proposal received intense opposition. Many of the presented arguments could still be used today. However, we argue that at least to some extent, the atmosphere has changed to favour proposed international TGC support.

One of the main concerns has been the possible effect on the national support schemes, namely feed-in tariffs. It is often argued that national schemes that have been most successful would be jeopardised by a common certificate system. There have also been clear statements against the harmonisation of support schemes. (EREC, 2008) (Klessmann, 2009) Taking into account the clear goals of harmonisation, the changes in renewable electricity penetration to markets and their competitiveness, it can be argued that this path of development should now be embraced rather than rejected. Renewables have developed to a point where they need to be exposed to market signals.

Drawbacks regarding the sovereignty of the Member States on their support policies have also been considered as a “knock-out criteria” for international certificate trade (Klessmann, 2009). It can, however, be equally argued that taking into consideration both the aims of the internal electricity market directive and the global nature of environmental issues, especially those caused by conventional fossil electricity production, a more common approach should be chosen. Recent cost developments due to cost-inefficient national implications of renewable support and very ambitious Community-level goals also contribute to the shift toward a more cost-efficient multilateral approach.

Another opposing argument has been that European certificate trade would decrease cost-effectiveness of technology-specific support. This would create a risk of overcompensating already mature technologies, giving rise to windfall profits. (Klessmann, 2009) This often-made argument is based on the premise that immature technologies should be strongly supported in order to promote their deployment in the markets. However, a strong case can be built against this statement, relying mainly on two key components. Firstly, as presented before, the EU has set very ambitious targets for future decades. Current support mechanisms will not be sufficient in achieving them. Current costs suggest that even reference development would be hard to maintain. Thus, overall cost-efficiency must be increased. A large potential for fulfilling this requirement lies in the suggested transition to European volume-based support, which would probably increasingly exhaust the potential for mature and low-cost renewable technologies. Secondly, the social discount rate in Europe is relatively high, implied by the statements that delaying the transition to a low-carbon society would increase the overall costs (Capros, 2014) (Capros, et al., 2012). Thus, renewable energy deployment should be made as rapid as technologically possible. This would suggest embracing the market-set order of development led by wind and solar power. As mentioned before, the dominant position of low-cost renewables can partly be offset by introducing national support schemes for embryonic technologies which would comply with the maturity rate of these technologies.

11.1.4. Guarantee of Origin as a multilateral Tradable Green Certificate

As presented in a recent position paper by EUROPEX, the need for a multilateral TGC system would be fulfilled by establishing Guarantees of Origin (GOs) as a European volume-based support scheme. (EUROPEX, 2014a)

As shown in previous chapters, a GO system is already highly developed and widely in use within the Community. It has a mature market[60] that reaches across Europe. The GO system is also based on EECS rules[61] which, when implemented, guarantee the compatibility and

[60] Market size over 300 TWh per year
[61] EECS standard is also formalized in a CEN/CENELEC standard

functionality of international certificate trade. EECS Rules are consistent with European Community law and relevant national laws, ensuring a reliable and secure framework. (AIB, 2014c) GOs also contain all the necessary data for being used in a TGC system (EUROPEX, 2014a).

Fagiani & Hakvoort have shown that regulatory changes regarding a common TGC market between Norway and Sweden have had a negative effect on certificate price volatility. (Fagiani & Hakvoort, 2014) The effect can be minimised in the case of transforming an existing disclosure system into a support mechanism. Furthermore, a GO-based disclosure system has already been able to supplement an existing TGC support scheme in Norway and Sweden, although the role of GOs have been minimal compared to the standalone TGC system (Raadal, et al., 2012).

It has been repeatedly underlined that transparency and consistency regarding the support legislation are key aspects in controlling any support system costs. (Aune, et al., 2008) (Söderholm, 2008) (Fagiani & Hakvoort, 2014) Implementers of the EECS rules, mainly the members of AIB, have already had to establish harmonised standards for creation, maintenance, transfer, cancellation and other processing of EECS certificates (AIB, 2014c). Thus, the framework for a support certificate market already exists, giving the investors transparency and certainty in scheme implementation details.

It has also been pointed out that attracting Member States to participate in a multilateral TGC support system benefits from having an existing system to benchmark. (Söderholm, 2008) Current GO systems should, however, expand to cover all electricity generation[62]. (EUROPEX, 2014a)

It can be argued that implementing a quota support scheme via an existing disclosure system would undermine the current functionality of GOs as tracking instruments. However, such effects would not occur if only new capacity is made eligible for support, leaving the already existing system intact. (Klimscheffskij, 2014)

This thesis thus concludes that an international volume-based support scheme could be best implemented as an extension of the current GO disclosure system.

[62] This recommendation also applies to current institution of GOs. (RE-DISS II, 2012)

11.2. Opening certificate trade to voluntary participation

The proposed approach to transform current national support schemes into a multilateral market-based mechanism is very ambitious, as it would require strong top-down leadership on the Community level, and intense advocacy promoting the overall benefits of such system among the public.

The transition to an international support system could be eased if voluntary participation was allowed.

From a financial point of view, allowing public access to the international certificate trade would mitigate investor risk, as it would initially expand the market potential and hopefully later the market size respectively. (Raadal, et al., 2012) This would reduce the support scheme cost and more importantly partly allocate the costs to actors most willing to promote renewable development (Klimscheffskij, 2011).

From the consumer's perspective, the willingness to pay for green electricity products mainly stems from the individual values of the buyer. These can be roughly divided into altruistic and egoistic motivators working parallel to one another. Self-image motivation seems to be the main driver behind consumer participation. It is accompanied by more altruistic drivers, like overall concerns for the environmental consequences. The main barriers to consumer participation often involve a shortage of information e.g. regarding the variety of products, environmental effects, or social norms and behaviour patterns of others. (David, 2014)

The below figure presents the formation of the willingness to pay for green electricity. As shown, the key individual values are affected by various factors and barriers.

David has also shown that a permanent transformation in consumer participation can be achieved by temporary campaigns and marketing efforts that would take the economy of relevant products beyond the model's "turning point[63]", creating a situation where buying green products would gradually become the social norm. (David, 2014)

[63] A concept of a point in economic development after which desired result is automatically reached regardless of later variations in model's input parameters.

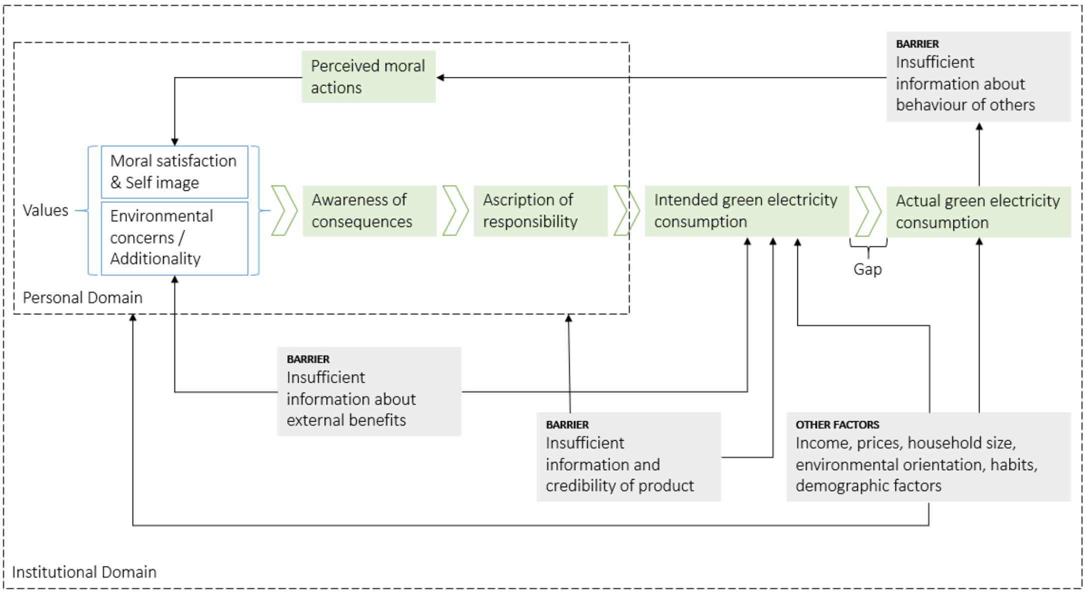

Figure 11.6: Formation of the willingness of consumers to pay for green electricity (David, 2014)

Voluntary access would also fulfil the principle of consumer choice. The development of GO markets (Figure 4.7: Issuing and cancellation volumes of GOs 2001-2013) shows that consumers are increasingly willing to purchase "green" electricity products. By comparing the demand and price of different GO products, it can be argued that relatively high prices can be demanded, as long as maximal reliability in rightful support distribution and allowance is provided. Most products display these traits via different third party labels attached to the original GO. Similar effects could be expected if GOs would be promoted to fulfil national quotas and targets. Willingness to pay for labelled electricity products indicates that price increase of GOs[64] would not necessarily decrease this demand if additional transparency and involvement in the mechanism are offered in return. Here, an analogy to emissions trading schemes (ETS) can be drawn where a significant market has developed for voluntary means of emission reductions. Although certificate prices in ETS are significantly higher than in the case of GOs, an increasing willingness to voluntarily participate in the scheme can be witnessed, mostly due to higher public confidence in the effects of the system.

Finally, from a regulatory point of view, a positive feedback loop of voluntary support can be observed. When allowed voluntary support is taken into account in policy design, the large public experiences increased involvement in the system. This further promotes voluntary participation, leading to an even greater public effect on renewable remuneration. As this phenomenon grows, governments are forced to increase transparency of support policies,

[64] to the level of e.g. Norwegian-Swedish Elcertificates

as it is increasingly relevant to a larger share of lay-people and commercial actors. This would finally lead to a steadier foothold of renewable policies and increased transparency toward investors – aspects that are both prone to reduce related costs. (Klimscheffskij, 2011)

12. Discussion – dark green products

This section will discuss the context and role of "dark green" products as a possible component of a TGC support system.

In many cases, the willingness of consumers to participate in the promotion of renewable energy sources is connected to the concept of additionality[65]. It is related to the consumers' demand to witness a change in development as a result of their action – to make a difference. Current disclosure systems only partly fill this demand because all renewable generation is included and power suppliers' green products can be built upon any renewable origin. Thus, the confidence in a disclosure system is partly hindered.

In a TGC support scheme, in theory, it becomes possible to offer consumers so-called dark green products. (Notice that this is currently not allowed/possible in the current quota systems e.g. the Swedish-Norwegian Elcertificates) These products would be based on the certificates from support-eligible generators having the potential to fulfil national (supplier) quota. A voluntary actor could, however, buy the certificate from the market, thus removing it from any possible quota. This would guarantee additionality by creating further demand for renewable investments beyond the scope of the original targets. As witnessed in the cases of emissions trading scheme and labelled renewable electricity, consumers are willing to pay higher prices for the allowances and the attributes if the reliability, transparency and additionality criteria are satisfied. This level of acceptable price could very well reach the value of current TGCs in the Swedish-Norwegian Elcertificate scheme.

[65] In the context of renewable energy adoption, additionality indicates the additional RES production compared to a Business As Usual case, due to a certain policy or action. (Klimscheffskij, 2011)

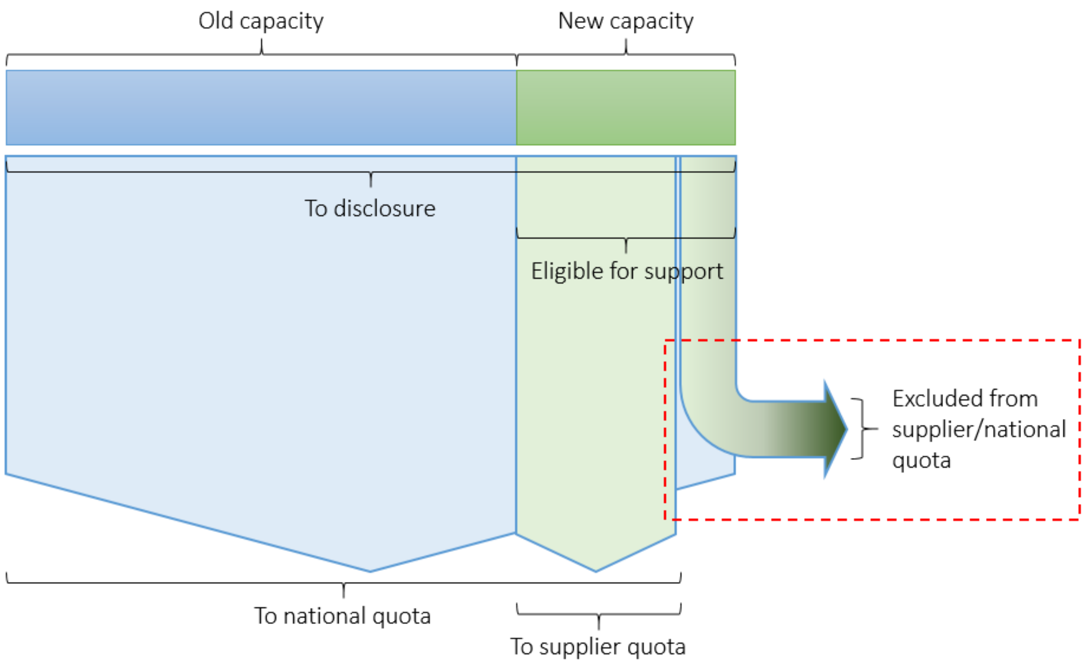

Figure 12.1: The position of dark green products in a certificate-based disclosure/support system

Currently, the above-described voluntary participation is not possible. Community level regulations prevent the voluntary increase in RES demand by means of cutting the amount of quota certificates available in volume-based support schemes. In price-based implementations, the alternative is out of the question by default because the support is not market-based. When designing a future framework for renewable energy support, this alternative should be kept in mind. Not least for its large potential for true consumer involvement.

13. Conclusions

The future environment surrounding renewable energy support in Europe will drastically differ from the situation that was prevalent during the end of the last decade, when the third legislative package came into force. In addition to the already present drive toward a low-carbon economy with clean generation technologies, new requirements have risen via exponential growth of renewables, their competitiveness, and their increasing market penetration, leading to increasing disturbances in the electricity markets. The struggle toward an Internal Electricity Market seems to have also gained an extra gear, resulting in additional pressure towards multilevel integration and harmonisation across Europe.

The current state of renewable support in Europe is not sufficient to achieve any of the five objective scenarios proposed by the European Commission. The alternative mechanism would have to provide a European approach by allocating support more cost-efficiently across national borders, addressing the need for growing renewables to be exposed to more market forces, taking into account the increased maturity of some renewable technologies, and providing a harmonised approach to cost and support allocation.

The recommended approach for such a future support system would be a multilateral tradable green certificate market, a European quota obligation scheme, based on the already existing framework and market of Guarantees of Origin. This system would lead to the most efficient allocation of available resources, provide sufficiently large and stable market to mitigate investment risk, and remove the channelling of support through government facilities by giving markets the power over the supply, demand and price of the certificates. The risk of uncontrolled remuneration growth due to poor volume predictability (as in price-based systems) is also diminished.

This alternative has already been proposed and discussed within the context of the previous legislative package proposals. However, as discussed, the markets and renewable technologies were too immature at the time to create this kind of common system. Some of the predictions and estimations presented as parallel to previous support mechanism debate have also proved to being flawed. Time has passed, and indicators of competitiveness, market penetration and resulting costs suggest that the time for this European transition has now come.

14. Future work

As stated in the research questions (1.1), this thesis has focused on the future framework of renewable energy support in Europe. On a geographical scale, this framework can be seen as a European level guidance for coordinating the integration of national support schemes. It is carried out on a rather theoretical level, yet it relies on up-to-date data and current developments in the field.

In order to make the proposed framework a viable option for policy makers and officials, a more detailed analysis of the possible implementation of the results should be pursued. The main focus should be put on the normative guidelines, taking a stepwise approach towards the transition into multilateral certificate trade. More focus should be put on national options in shifting to a common support framework.

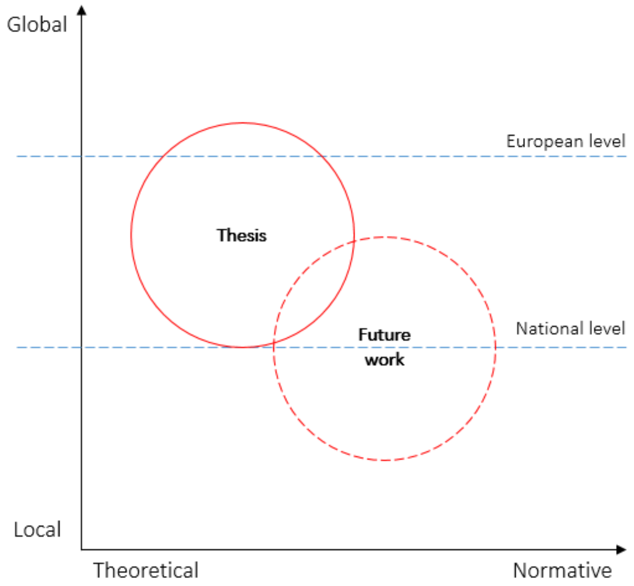

Figure 14.1: Relative position of (majority of) future work as compared to the scope of work at hand

In the research limitations section (1.2), the emissions trading scheme was excluded from this study. This thesis merely stated that the basis for the coexistence of these two mechanisms can be found. It is thus imperative to also study the overlapping effects of renewable energy support and the ETS.

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